"EVALUATION OF IMPACT ON RISK ASSESSMENT OF INFERIOR ALVEOLAR NERVE INJURY OR EXPOSURE AFTER COMPARISON OF 2-D (OPG) IMAGING AND 3-D (CBCT) IMAGING FOLLOWING 3RD MOLAR SURGERY: A PROSPECTIVE CLINICAL STUDY"

Dissertation submitted to

SANTOSH DEEMED TO BE UNIVERSITY, GHAZIABAD, NCR, DELHI

In partial fulfillment of the requirement for the degree of

MASTER OF DENTAL SURGERY

In the speciality of

ORAL AND MAXILLOFACIAL SURGERY

By

Dr. RAJIV KUMAR SINGH

Under the guidance of

Dr. AMIT B. LALL

Professor and Head

DEPARTMENT OF ORAL AND MAXILLOFACIAL SURGERY,

SANTOSH DENTAL COLLEGE AND HOSPITALS

GHAZIABAD-201009, NCR, DELHI, INDIA.

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Date:

Place: Ghaziabad

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Dr. Rajiv Kumar Singh

Date:

Place: Ghaziabad

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Date:

Place: Ghaziabad

(Prof.) DR. AKSHAY BHARGAVA
MDS (Prosthodontics)
AFAAID, DICOI, DWCOI
Dean
Santosh Dental College & Hospital
Ghaziabad,NCR, Delhi

Deemed to be University
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CERTIFICATE BY THE GUIDE

This is to certify that the dissertation titled **"EVALUATION OF IMPACT ON RISK ASSESSMENT OF INFERIOR ALVEOLAR NERVE INJURY OR EXPOSURE AFTER COMPARISON OF 2-D (OPG) IMAGING AND 3-D (CBCT) IMAGING FOLLOWING 3RD MOLAR SURGERY: A PROSPECTIVE CLINICAL STUDY"** is a bonafide genuine research work carried out by **Dr. Rajiv Kumar Singh** in partial fulfillment of the requirement for the degree of **MASTER OF DENTAL SURGERY** in the specialty of **ORAL AND MAXILLOFACIAL SURGERY.**

Date:

Place: Ghaziabad

GUIDE:
Dr. Amit B. Lall
MDS, DNB
Professor and Head
Department of Oral & Maxillofacial Surgery
Santosh Dental College & Hospital
Ghaziabad, NCR, Delhi

CO-GUIDE:
Dr. Mayank Singhal
MDS, Ph.D.
Professor
Department of Oral & Maxillofacial Surgery
Santosh Dental College & Hospital

Deemed to be University
(Established u/s 3 of the UGC Act, 1956)

CERTIFICATE BY HEAD OF THE DEPARTMENT

This is to certify that the dissertation titled **"EVALUATION OF IMPACT ON RISK ASSESSMENT OF INFERIOR ALVEOLAR NERVE INJURY OR EXPOSURE AFTER COMPARISON OF 2-D (OPG) IMAGING AND 3-D (CBCT) IMAGING FOLLOWING 3RD MOLAR SURGERY: A PROSPECTIVE CLINICAL STUDY"** being submitted by **Dr. Rajiv Kumar Singh** in partial fulfillment of regulation for the award of the degreeof **MASTER OF DENTAL SURGERY** is based on the bonafide work carried outby him under my direct guidance and supervision and completed to my full satisfaction.

Date:

Place: Ghaziabad

Dr. Amit B. Lall
MDS, DNB
(Professor and Head)
Department of Oral & Maxillofacial Surgery,
Santosh Dental College & Hospital
Ghaziabad, NCR, Delhi

Deemed to be University
(Established u/s 3 of the UGC Act, 1956)

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ACKNOWLEDGEMENT

This dissertation is the culmination of 2.5 years of hard work at Santosh Dental College & Hospital, Ghaziabad. There are numerous people I wish to thank for contributing to this work Firstly, I would like to thank the Almighty for always having bigger plans for me and helping me to conquer my fears vivaciously.

I fall short of words to express my gratitude to my mother, Mrs. Seema Devi for always beholding me with tender, love and care and motivating me in all the ways to excel beyond my imagination. I am highly indebted to my maternal grandmother Mrs. Kaushalya Devi who taught me to never give up in tough times.

I specially look upto my younger sister Pooja Singh who's been my bed rock and biggest supporter in all my achievements and failures.

I will always have immense sense of gratitude forever to my guide, my mentor Dr. Amit B. Lall, Professor & Head, Department of Oral and Maxillofacial Surgery, Santosh Dental College who has been the guiding heliograph in all my academic endeavours. His determination and intrepidity have constantly incubated, developed and refined my clinical and academic deeds. His unstoppable motivation empowers me incessantly to improvise my clinical acumen and instills within me the spoken and unspoken fundamental dictum of surgery. His diligence and aspirational perception towards his work never ceases to inspire me. His invaluable advice, ingenious insight, expert guidance, and his caring support have made this study possible in its entirety. His teachings have constantly made me strive for my best. He has molded, and reshaped me as an individual. As I express my boundless gratitude, he has also taught me that the highest appreciation is to not utter words but to live by them.

I wish to express my altitude sense of gratitude to my co-guide Dr. Mayank Singhal, Professor, Department of Oral & Maxillofacial Surgery, Santosh Dental College, for his generous and useful support in the completion of this work. His remarkable insight and profound knowledge have uplifted my intellectual ambitions. He always welcomed my work with kind, positive and distinctive inputs effortlessly.

I wish to express my sincere gratitude to Dr. Lokesh Chandra, Professor, Department of Oral & Maxillofacial Surgery, Santosh Dental College, for his exhilarating experience and sagacity. He has helped me immensely in shaping and sharpening my surgical skills.

I wish to record my thanks to Dr. Anupam Bhardwaj, Reader, Department of Oral & Maxillofacial Surgery, Santosh Dental College for his constant support and enthralling motivation. His words of wisdom guided me throughout my journey.

I express my heartfelt thanks to Dr. (Prof.) Akshay Bhargava, Dean and Principal, Santosh Dental College, who provided me with this learning opportunity, which pushed me to go beyond my limits and dream for the best. His valuable insights made a strong impression on me and my work.

My deepest regards to Dr. P. Mahalingam, Chairman, Santosh Deemed to be University, for providing me with all the facilities for completion of this research endeavour. I also express my sincere thanks to all the teaching and non-teaching staff for their support throughout this endeavour.

I wish to extend my thanks to all my post graduate juniors: Dr. Puja Agarwal, Dr. Akriti Singh, Dr. Sreejita Mukherjee, Dr. Harshita Sharma, Dr. Richa Sharma, Dr. Janmajay Jena, Dr. Shweta Sidbatte, Dr. Drishya Mohan and Dr. Shraddha Sonwane.

I would extend my heartfelt gratitude to my seniors Dr. Sonakshi R. Singh and Dr. Jahanvi Mishra for teaching me righteousness, discipline and resilience on this rocky endeavour.
And lastly I would like to extend a big thanks to my Co-Pg Dr. Prakriti Bhardwaj, Dr. Deekksha Baghel, Dr. Rani Raginee Rajhans, Dr. Pratibhchandra J P for being my pillar of strength through all the tough times and prepping me to stand tall like a warrior.
Thanking you…

Dr. Rajiv Kumar Singh

TABLE OF CONTENTS

S. NO.	CONTENTS	PAGE NO.
1.	Introduction	1 - 3
2.	Aim & Objectives	4
3.	Review of Literature	5-23
4.	Materials and Methods	24-30
5.	Representative Cases	31-49
6.	Results	50-62
7.	Discussion	63-73
8.	Conclusion	74
9.	Bibliography	75-83
10.	Annexures	84- 95
11.	Master Chart	96

LIST OF FIGURES

S. NO.	LEGENDS	PAGE NO.
1	OPG machine	25
2	CBCT machine	25
3	TFT monitor (Romex software / Romexis)	26
4	Basic surgical kit for impaction surgery	26
5.1	Intra-oral pre-op photograph	31
5.2	Pre-operative OPG: Winters's classification- Mesio-angular impacted 48, Pell & Gregory's classification- Position A, Class II. Pederson difficulty index- 4 (slightly difficult). Rood and Shehab Criteria- Darkening of root, interruption of white line of canal, narrowing of canal	31
5.3	Pre-operative CBCT (Coronal section) reveals direct contact of IAC with the root apex of third molar and also reveals thinning of the lingual cortical plate. Mesial and distal roots are seen which are separated and causing thinning and indentation of lingual cortex. Mesial root is bifurcated into two separate root apex at apical 1/3rd level.	32
5.4	Pre-operative CBCT (Axial section) reveals type 2 morphologic shape of the bone in the third molar region and also reveals that inferior alveolar canal courses inferiorly and buccally to the root apices, there is point contact of IAN canal with apical 1/3rd of mesial root. Evidence of decortication and clear compression of nerve (IAN).	32
5.5	Pre-operative CBCT (Sagittal section) reveals mesio-angular type of impaction of 48 and also reveals that the apical 1/3rd of the mesial root is abutting the IANC with mild narrowing of the IANC observed.	32
5.6	Modified Ward's incision	33
5.7	Extraction socket of 48	33
5.8	Extracted tooth 48	33
6.1	Intra-oral pre-op photograph	34

LIST OF FIGURES

S. NO.	LEGENDS	PAGE NO.
6.2	Pre-operative OPG: Winters's classification- Disto-angular 38, Pell and Gregory's classification- Position- B, Class II. Pederson difficulty index- 8. Rood and Shehab criteria- Darkening of root, Interruption of white line of canal.	34
6.3	Pre-operative CBCT (Coronal Section) reveals direct contact of IAC with respect to the root apex of third molar and also reveals thinning of the lingual cortical plate. IAN courses in lingual subcortical region caudal to root(s) apices with indentation-impingement of superior cortex.	35
6.4	Pre-operative CBCT (Axial section) reveals type 3 morphologic shape of the bone in the third molar region. Two roots (mesial and distal root) Canal is placed lingual to the roots of third molar. IAN is running lingually to the distal root, there is direct contact of IAN with apical 1/3rd of distal root.	35
6.5	Pre-operative CBCT (Sagittal section) reveals disto-angular type of impaction of 38. IAN is running apically and lingually, there is direct contact of IAN with apical 1/3rd of distal root. Evidence of decortication and clear compression of nerve (IAN) towards the lingual cortex. Sagittal section reveals fusion of both mesial and distal roots.	35
6.6	Ward's incision	36
6.7	Extraction socket of 38	36
6.8	Extracted tooth 38	36
7.1	Intra-oral pre-op photograph	37
7.2	Pre-operative OPG: Winter's classification- Horizontally impacted 38. Pell & Gregory's classification- Position B, Class II. Pederson difficulty index- 6 (moderately difficult). Rood and Shehab criteria- Darkening of root, interruption of white line of canal, narrowing of canal	37

LIST OF FIGURES

S. NO.	LEGENDS	PAGE NO.
7.3	Pre-operative CBCT (Coronal section) reveals direct contact of IAC with the root apex of third molar and also reveals thinning of the lingual cortical plate. Tooth is oriented more towards the lingual cortical plate.	38
7.4	Pre-operative CBCT (Axial section) reveals type 2 morphologic shape of the bone in the third molar region. IAN is running lingually to the distal root, there is direct contact of IAN with apical 1/3rd of distal root. Evidence of decortication and clear compression of nerve (IAN) towards the lingual cortex.	38
7.5	Pre-operative CBCT (Sagittal section) reveals horizontal type of impaction of 48. Tooth 38 shows two roots, mesial and distal with root formation complete. Sagittal section reveals that the apical 1/3rd of the mesial root is abutting the IANC with mild narrowing of the IANC observed.	38
7.6	Modified Ward's incision	39
7.7	Extraction socket of 38	39
7.8	Extracted tooth 38	39
8.1	Intra-oral pre-op photograph	40
8.2	Pre-operative OPG: Winters's classification- Disto-angular 48. Pell and Gregory's classification- Position- A, Class II. Pederson difficulty index- 7. Rood and Shehab criteria- Darkening of root, interruption of white line of canal	40
8.3	Pre-operative CBCT (Coronal section) reveals direct contact of IAC with the root apex of third molar and also reveals thinning of the lingual cortical plate. Tooth is oriented more towards the lingual cortical plate.	41
8.4	Pre-operative CBCT (Axial section) reveals type 2 morphologic shape of the bone in the third molar region. Two mesial roots (mesio-buccal and mesio-lingual) and one distal root. Canal is placed lingual to the roots of third molar. IAN is running lingually to the distal root, there is direct contact of IAN with apical 1/3rd of distal root.	41

LIST OF FIGURES

S. NO.	LEGENDS	PAGE NO.
8.5	Pre-operative CBCT (Sagittal section) reveals disto-angular type of impaction of 48. IAN is running lingually to the distal root at apical 1/3rd level, there is direct contact of IAN with apical 1/3rd of distal root. Evidence of decortication and clear compression of nerve (IAN) towards the lingual cortex.	41
8.6	Ward's incision	42
8.7	Extraction socket of 48	42
8.8	Extracted tooth 48	42
8.9	Mapping of neuro-sensory deficit (post-op day 1 to post-op day 90)	43
9.1	Intra-oral pre-op photograph	44
9.2	Pre-operative OPG: Winter's classification- Mesio-angular impacted 38. Pell & Greogory's classification- Position B, Class II. Pederson difficulty index- 5 (moderately difficult). Rood & Shehab's Criteria- Darkening of root, narrowing of roots, interruption of white line of canal	44
9.3	Pre-operative CBCT (Coronal section) reveals direct contact of IAC with the root apex of third molar and also reveals thinning of the cortical plate. Tooth is oriented more towards the lingual cortical plate.	45
9.4	Pre-operative CBCT (Axial section) reveals type 3 morphologic shape of the bone in the third molar region. Also reveals direct contact of IAC with the root apex of third molar Canal is placed lingual to the roots of third molar.	45
9.5	Pre-operative CBCT (Sagittal section) of third molar reveals mesio-angular type of impaction of 38. Mesial and distal roots (2 roots) are seen fused in the apical third.	45
9.6	Ward's incision	46
9.7	Extraction socket of 38	46
9.8	Extracted tooth 38	46
10.1	Intra-oral pre-op photograph	47

LIST OF FIGURES

S. NO.	LEGENDS	PAGE NO.
10.2	Pre-operative OPG: Winter's classification- Mesio-angular impacted 38. Pell & Greogory's classification- Position A, Class II.Pederson difficulty index- 4 (slightly difficult). Rood & Shehab's Criteria- Darkening of root, Narrowing of canal, Dark and bifid apex	47
10.3	Pre-operative coronal section of CBCT reveals direct contact of IAC with the root apex of third molar and also reveals thinning of the lingual cortical plate.	48
10.4	Pre-operative axial section of CBCT reveals type 2 morphologic shape of the bone in the third molar region and also reveals direct contact of IAC with the root apex of third molar. IAN courses in inter-radicular region of DB-DL rootlets and MB-ML rootlets in apical area with indentation-impingement of superior cortex.	48
10.5	Pre-operative Sagittal section of CBCT reveals mesio-angular type of impaction of 38 and also reveals direct contact and compression of IAC with the root apex of third molar	48
10.6	Modified Ward's incision	49
10.7	Extraction socket of 38	49
10.8	Extracted tooth 38	49

LIST OF TABLES

S. NO.	LEGENDS	PAGE NO.
1	Pederson difficulty index	28
2	Difference between the two imaging techniques (OPG and CBCT) in terms of classification distribution	50
3	Pell and Gregory's classification for impacted mandibular third molars show a distribution across the different positions and classes	51
4	OPG evaluation based on seven radiographic signs (Rood and Shehab criteria)	52
5	Distribution of Pederson difficulty scores among study participants	53
6	Correlation between Pederson difficulty score and angulation of impacted mandibular third molar	54
7	Positional relationship of roots of impacted molar with the inferior alveolar nerve	55
8	Contact of the impacted third molar with IAN	56
9	Relation of the impacted third molar with the cortical plate	56
10	Intra-operative assessment of the study subjects	57
11	Morphologic shape of the bone in the third molar region	58
12	Number of roots among study subjects	59
13	Neurosensory deficit among study subjects	60

LIST OF GRAPHS

S. NO.	LEGENDS	PAGE NO.
1	Difference between the two imaging techniques (OPG and CBCT) in terms of classification distribution	50
2	Pell and Gregory's classification for impacted mandibular third molars show a distribution across the different positions and classes	51
3	OPG evaluation based on seven radiographic signs (Rood and Shehab's criteria)	52
4	Pederson Difficulty Scores based on type of impaction	55
5	Intra-operative assessment of the study subjects	58
6	Neurosensory deficit among study subjects	61

LIST OF PIE CHART

S. NO.	LEGENDS	PAGE NO.
1	Illustrating the percentage distribution among study participants indicating the relative frequency of each difficulty level in mandibular third molar extraction	53
2	Contact of the impacted third molar with IAN	56
3	Relation of the impacted third molar with the cortical plate	57
4	Morphologic shape of the bone in the third molar region	59
5	Number of roots among study subjects	59

LIST OF ANNEXURES

S. NO.	ANNEXURES	PAGE NO.
1.	Ethical Committee Clearance Form	84
2.	Anti-Plagiarism Report	85
3.	Patient Proforma	86–93
4.	Consent Form	94-95

LIST OF ABBREVIATIONS

S. NO.	ABBREVIATIONS	FULL FORM
1.	IMTM	Impacted mandibular third molar
2.	IAN	Inferior alveolar nerve
3.	CBCT	Cone-beam computed tomography
4.	OPG	Orthopantomogram
5.	DPT	Dental panoramic tomographs
6.	MNBR	Multi-projection narrow-beam radiography
7.	IANI	Inferior alveolar nerve injury
8.	DOR	Diagnostic odds ratio
9.	DR	Darkening of roots
10.	IWL	Interruption of the white line
11.	CT	Computed tomography
12.	PAN	Panoramic radiography
13.	PLR	Positive likelihood ratios
14.	CI	Confidence intervals
15.	SCT	Spiral computed tomography

INTRODUCTION

An impacted tooth is one that cannot emerge properly through the gums due to causes such as malposition, insufficient space, or physical obstructions along its eruption path. Left untreated, lower impacted teeth can lead to discomfort, pain, and various dental complications.[1] In oral surgery, the surgical removal of IMTM (impacted mandibular third molar) is a common procedure that is carried out for both preventative and therapeutic purposes.[2,3] However, it is frequently associated with complications such as trismus, infection, dry socket, discomfort, swelling, and bleeding.[4,5] Among these, transient or permanent injury to the IAN is the most concerning.[4] The mandibular canal, a crucial anatomical structure within the mandible, houses the IAN, which provides sensation to the teeth, gums, and lower lip. It is crucial to comprehend the exact position and trajectory of the canal with respect to the lower impacted teeth and surrounding bone while extracting IMTM. The third molar root has a close relationship to the mandibular canal, and IAN runs parallel to the mandibular artery and vein. Its corticalization, morphology, and caliber regularly change depending on the tooth.

After the lower third molar surgery, the risk of persistent IAN injury is less than 1%, whereas the chance of transient IAN injury varies from 0.6% to 5.3%.[4] Such complications not only affect patients through potential sensation loss but also carry significant medicolegal implications.[6,7] Thus, pre-operative radiographic examination is essential to predict and mitigate these risks. For pre-operative evaluation, a variety of radiographic modalities are used, such as computed tomography (CT), CBCT, DentaScan, orthopantomograms (OPG), and periapical radiographs.[3,4] A preoperative radiographic assessment of the anatomical structure and its relationship to the mandibular canal is essential to evaluate the risk of IAN damage associated with an impacted wisdom tooth. OPG is frequently utilized as a preliminary examination technique to assess the impaction type, impacted wisdom tooth angulation, and root morphology.[8,9] OPG, a two-dimensional (2D) imaging method, is unable to accurately establish the spatial connection between the lower impacted wisdom tooth and the IANC. The overlapping or distortion of images can lead to misinterpretation and incorrect clinical decisions.[10-12] These limitations greatly reduce its diagnostic precision and effectively rule it out as a necessary measurement before the surgical removal of the lower impacted wisdom tooth.

CBCT has emerged as a superior imaging technique, offering three-dimensional (3D) visualization of anatomical structures. One of the primary concerns observed in 3D

radiographic imaging is the absence of canal corticalization where it contacts the impacted tooth. By providing comprehensive information on the spatial connections between the IMTM and the IAC, it enhances preoperative risk assessment. Compared to OPG, CBCT offers advantages such as high resolution, 3D imaging, buccolingual visualization, and lower radiation exposure.[11-13] Because of these advantages, CBCT is especially useful when there is a high risk of nerve damage or when the lower impacted wisdom tooth is located close to the IAC.[14] Due to its far lower radiation dose than CT, CBCT can be used in applications that were previously hard to justify because of radiation exposure concerns. However, it is not advised as the primary radiography technique of choice due to its comparatively high cost.[15]

The IMTM and the IAC were found to be strongly correlated by Rood and Shehab's seven radiological markers. Four of the signs are associated with the tooth root (darkening, deflection, narrowing of the roots, and bifid and dark apex), while three are associated with changes in the appearance of the IAC (diversion, narrowing, and interrupted white lines of the canal).[16-19] Root darkening was the most prevalent OPG sign, whereas disruption of the canal's white line was the second most common criteria Ghai and Choudhury[9], Rood and Shehab[17] and Sedaghatfar et al.[19]. According to Tassoker[4], diversion of inferior alveolar nerve canal in OPG was a single risk factor for the absence of cortication and was around twelve times more likely to occur than other OPG symptoms. A considerable link was found between the disruption of the canal's white line on OPG and a higher probability of having an IAC wall defect Fauzi et al.[20].

CBCT's ability to dynamically evaluate anatomical structures in axial, sagittal, and coronal planes without overlap makes it invaluable for pre-operative planning. During mandibular third molar extractions, oral surgeons can lower the risk of IAN damage by using CBCT to identify safe and risky zones. CBCT is recommended only when panoramic radiographs indicate a close relationship between the impacted third molar and the mandibular canal. The capacity to identify the direction of luxation and surgical extraction of the third molar, which is normally impossible with a panoramic radiograph alone, is a crucial supplementary benefit of CBCT imaging.[21]

There is a significant chance of IAN damage when the lower impacted wisdom tooth, which is located far below the cemento-enamel junction of the second molar, is surgically removed. Detailed radiographic analysis is thus an essential pre-operative step, providing critical insights into tooth position, root morphology, and the proximity of vital structures. Failure to perform thorough pre-operative assessments may result in significant complications for

patients and substantial medicolegal consequences for clinicians.[6]

According to Tantanapornkul et al.[22], when it came to predicting exposure of the inferior alveolar nerve (IAN), CBCT showed noticeably better sensitivity (93%) and specificity (77%) than OPG, which had sensitivity (70%) and specificity (63%). In prospective investigations comparing CBCT and OPG to predict IAN exposure following third molar surgery, Hasani et al.[23] found that CBCT was much more accurate than OPG (67.7% accuracy rate), correctly predicting 93.3% of cases.

The accurate assessment of impacted teeth and their relationship to the IAC is crucial for minimizing complications during mandibular third molar extractions. While OPG serves as a useful initial diagnostic tool, CBCT is recommended for high-risk cases due to its superior diagnostic capabilities. CBCT improves patient safety and clinical results by allowing for precise surgical planning. This study aims to correlate the assessment of the risk ofinferior alveolar nerve injury after comparing pre-operative 2-D(OPG) and 3-D (CBCT) imaging with the intraoperative exposure of IAN and its clinical outcome in the postoperative phase.

AIM AND OBJECTIVES

AIM:

This study aims to correlate the assessment of the risk ofinferior alveolar nerve injury after comparing pre-operative 2-D(OPG) and 3-D (CBCT) imaging with the intraoperative exposure of IAN and its clinical outcome in the postoperative phase.

OBJECTIVES:

- To predict the risk of IAN exposure/injury based on evaluation of OPG x-ray (2D Imaging).
- To predict the risk of IAN exposure/injury based on evaluation of CBCT (3D Imaging).
- To find the association between predicted risk and observed clinical outcomes for IAN injury /exposure.

REVIEW OF LITERATURE

Bell GW (2004)[24] conducted a study to compare preoperative radiological observations from dental panoramic tomographs (DPT) with surgical findings at the removal of third molars with respect to the inferior alveolar nerve. Their results revealed that the most common radiographic appearance of a relation between the mandibular third molar tooth and the inferior alveolar nerve was superimposition in 110 teeth (37%). The next most commonly observed radiographic sign was that the root apex just touched the upper border of the outline of the neurovascular bundle (96 teeth, 32%). In 55 teeth (18%), there was a separation of more than 1 mm between the roots and the neurovascular bundle. The apical region was the site of an intimate relation between root and nerve in 25 teeth (8%). In the remaining 10 teeth, the intimate relation was within 5 mm of the anatomical apex of the root, with one exception where it was 7 mm. They concluded that DPT should be regarded as an acceptable, although not ideal, method of preoperative imaging when mandibular third molar teeth were to be removed, and its limitations should be acknowledged.

Sedaghatfar M, August MA, Dodson TB (2005)[19] conducted a study to estimate the sensitivity and specificity of panoramic radiographic findings in relation to inferior alveolar nerve (IAN) exposure after mandibular third molar (M3) extraction. Their study sample composed of 230 patients, with 423 mandibular third molars evaluated and surgically removed. Following the third molar extraction, the IAN was visualized in 24 (5.7%) extraction sites. Four of the radiographic signs were statistically associated with IAN exposure (P < or = .05). The sensitivities and specificities of the 4 radiographic findings ranged from 0.42 to 0.75 and 0.66 to 0.91. The preoperative estimate of IAN exposure likelihood was statistically associated with IAN exposure after mandibular third molar extraction. They concluded that four radiographic findings (darkening of the tooth root, narrowing of the tooth root, interruption of the white lines, and diversion of the canal) were statistically associated with IAN exposure following mandibular third molar extraction. The surgeon's overall risk estimate based on the panoramic radiograph was also statistically associated with an increased risk of IAN exposure.

Tantanapornkul W, Okouchi K, Fujiwara Y et al (2007)[22] conducted a study to evaluate the diagnostic accuracy of cone-beam CT compared with panoramic images in predicting neurovascular bundle exposure during extraction of impacted mandibular third molars. Cone-beam CT and panoramic images of 142 impacted mandibular third molars were prospectively

evaluated to assess tooth relationship to the mandibular canal. They concluded that the sensitivity and specificity were 93% and 77% for cone-beam CT as compared to 70% and 63% for panoramic images, respectively. Cone-beam CT was significantly superior to panoramic images in both sensitivity and specificity.

Nakamori K, Fujiwara K, Miyazaki A et al (2008)[25] conducted a study to evaluate the relationship between lower third molars and the inferior alveolar canal (IAC) using panoramic radiographs and assessed criteria for CT evaluation. They found that among 119 teeth that underwent CT, 40.3% showed absence of cortication, and IAN injury occurred in 7 cases (1%). Specific panoramic signs—superimposition, root darkness, and IAC changes—were strongly associated with the absence of cortication. They concluded that Rood's criteria reliably predict third molar-IAC contact, guiding the need for CT scans to assess IAN injury risk.

Nakayama K, Nonoyama M, Takaki Y et al (2009)[26] conducted a study to assess the capacity of dental 3-dimensional computed tomography (3D-CT; cone-beam CT) to predict the exposure and injury of the inferior alveolar nerve (IAN) after mandibular third molar extractions. Intraoperative IAN exposure was observed in 17 (49%) contact cases and 2 (11%) noncontact cases on dental 3D-CT images. Out of 53 surgically extracted cases after dental 3D-CT examinations, IAN injury occurred in 8 cases (15%). IAN exposure led to IAN injury in 36.8% of cases, whereas IAN injury occurred in only 2.9% of cases without IAN exposure. Although the incidence of IAN injury in the molar-canal contact cases was 23%, all 8 cases with IAN injury (100%) were included in these contact cases. They concluded that when viewing the anatomic relation between the IAN and mandibular third molar root apices using dental 3D-CT, contact of the 2 anatomic structures results in an increased risk for IAN exposure or injury.

Palma-Carrió C, García Mira B, Larrazabal Morón C et al (2010)[18] conducted a literature review on preoperative radiographic signs in orthopantomography (OPG) and computed tomography (CT) associated with the risk of inferior alveolar nerve damage during the surgical extraction of lower third molars (LTMs).In their reviewed literature, radiographic signs in the OPG that indicated a relationship between the LTM and the inferior alveolar canal were considered a risk factor for nerve damage. These signs were darkening and deflection of the root and diversion and interruption in the white line of the canal. In the majority of these studies, the routine use of CT was not justified and was only recommended when radiographic signs appeared in the OPG that demonstrated a direct anatomical relationship between the LTM and the canal. In the CT, the absence of cortical bone in the canal implied contact

between the root of the LTM and the canal and was related to the presence of some radiographic signs in the OPG. They concluded that some studies demonstrated that despite the absence of cortical bone, the risk of lesion or exposure of the nerve during the extraction of LTM was low.

Suomalainen A, Ventä I, Mattila M et al (2010)[27] conducted a study to compare the reliability of cone-beam computerized tomography (CBCT) with that of other radiographic methods in preoperative radiographic determination of the number of roots of lower third molars and their relationship to the inferior alveolar canal (IAC). Forty-two teeth were clinically studied and imaged using CBCT and other imaging methods—panoramic radiography, multi-projection narrow-beam radiography (MNBR), and cross-sectional tomography. Their results showed that the kw coefficients for the estimated number of roots between panoramic radiographs and CBCT as well as the intraoperative findings showed excellent agreement for the assessment of CBCT images and good agreement for the assessment of panoramic images using prevalence-adjusted and bias-adjusted values. Cone-beam CT showed a perfect match between intra- and interobserver readings and when compared with the gold standard to locate the IAC. The MNBR stereographic technique proved to be unreliable and interpreter sensitive in their study. They concluded that CBCT is a reliable means of determining the location of the IAC and its relationship to the roots of the lower third molar, and in this respect was more reliable than MNBR and cross-sectional tomography.

Susarla SM, Sidhu HK, Avery LL et al (2010)[28] conducted a study to assess the relationship between computed tomography (CT) evaluation of inferior alveolar nerve (IAN) canal cortical integrity and intraoperative IAN exposure in high-risk patients identified through panoramic imaging. The primary predictor was cortical integrity (intact or interrupted) on coronal CT, with cortical defect length as a secondary variable. Their results showed that cortical integrity had high sensitivity but low specificity for predicting IAN exposure. No cases of postoperative IAN paresthesia or anesthesia were observed. The study concluded that a cortical defect >3 mm increases the risk of IAN exposure, making defect length a valuable predictor independent of imaging method or slice thickness.

Ghaeminia H, Meijer GJ, Soehardi A et al (2011)[29] conducted a study to evaluate the role of cone beam computed tomography (CBCT) in the treatment of patients with impacted mandibular third molars at increased risk of inferior alveolar nerve (IAN) injury. Subjects with an increased risk of IAN injury, as diagnosed on panoramic radiographs, were enrolled in their study and underwent additional CBCT imaging. Their results revealed that the study

sample consisted of 53 impacted third molars from 40 patients. A statistically significant difference was present between risk assessment for IAN injury based on panoramic radiography and CBCT imaging. A significant correlation was also seen for the vertical relationship of the third molar with the mandibular canal and the difference in risk assessment between CBCT images and panoramic radiographs. In cases where the root apex was positioned more caudal to the inferior border of the mandibular canal, the risk of injuring the IAN was assessed significantly lower after reviewing the CBCT images. They concluded that, if there was an intimate relationship between the third molar and mandibular canal, additional CBCT imaging was needed to inform the patient more adequately about the risk of nerve damage, and to improve surgical planning, thereby preventing movements of the roots causing pressure on the mandibular canal or the careless use of burs or elevators.

Khan I, Halli R, Gadre P et al (2011)[30] conducted a study to evaluate the potential advantages of spiral computed tomography and compared its efficacy as a presurgical planning tool with orthopantomography in patients with impacted mandibular third molars showing proximity to the inferior alveolar canal on an orthopantomogram. A total of 48 patients, 21 men and 27 women, within the age range of 19 to 50 years, were included in their study. All the selected patients first underwent an OPG, and if OPG revealed close proximity of the impacted third molar to the IAC, SCT scan in coronal and axial sections was performed. Their results revealed that the narrowing of the IAC while approaching the third molar root apex and diversion/deviation of the IAC while approaching the third molar roots, a probability value was found to be greater, which made these radiographic parameters statistically insignificant, whereas for the other 3 radiographic markers, namely, superimposition, increased radiolucency, and interruption of the radiopaque superior corticated margin, the probability value was found to be less, making the presence of these radiographic parameters statistically significant. They concluded that the results of their study may lead to some guidelines for oral surgeons who must decide whether a SCT scan is needed in addition to preoperative OPG for a patient who may undergo third molar removal. One should be more cautious if the 3 radiographic markers apart from the diversion or deviation of the IAC were positive on OPG, and this is of particular importance in developing countries where SCT is not available in all the centers.

Lübbers HT, Matthews F, Damerau G et al (2011)[31] conducted a study to describe and estimate the frequencies of anatomic variations of lower third molars in patients with panoramic findings at high risk for inferior alveolar nerve (IAN) injury. Spatial relationship to the IAN, type of angulation, root configuration and maturation were primary variables in

their study. Their results showed that close relationship to the IAN was seen in 69.7%, and in 45.1% the diameter of the mandibular canal was reduced. In 52.8% the IAN was vestibular and in 37.3% lingual to the roots, there were 9.9% with an inter- or intra-root course. Most teeth had 1 or 2 roots (86.7%), but 13.3% had 3 roots. Mesial angulation was the main type (40.2%), followed by vertical (29%), horizontal (13.9%), distal (10.2%), and transverse (6.8%) positions. Based on the range of variations in the course of the nerve and the number of roots, they recommend 3D imaging before surgical removal of a lower third molar that shows signs of a close relationship to the IAN.

Eyrich G, Seifert B, Matthews F et al (2011)[32] conducted a study to identify factors that lead to a higher risk of IAN impairment after surgery. In their study a total 515 surgical third molar removals with 3-dimensional (3D) imaging before surgical removal were retrospectively evaluated for IAN impairment, in addition to 3D imaging signs that were supposed predictors for postoperative IAN disturbance. Their results showed that the overall IAN impairment rate in their study was 9.4%. Univariate analysis showed narrowing of the IAN canal, direct contact between the IAN and the root, fully formed roots, an IAN lingual course with and without perforation of the cortical plate, and an intra-root position of the IAN as predictors of postoperative IAN impairment. Multivariate analysis showed narrowing of the IAN canal and direct contact to be the strongest independent predictors. They concluded that three-dimensional imaging is useful for predicting the risk of postoperative IAN impairment before surgical removal of impacted lower third molars. The low IAN impairment rate seen in their study—compared with similar selected study groups in the literature of the era before 3D imaging— indicates that the availability of 3D information was decreasing the risk for IAN impairment after lower third molar removal.

Katakam SK, Shankar U et al (2012)[33] conducted a study to find evidence for justifying the use of computed tomography and orthopantomography as a diagnostic modality, prior to surgical intervention of impacted mandibular third molar. In their study, they found that out of seven signs given by Rood, the most common radiographic sign observed was darkening of roots (42.88%), followed by narrowing of apex (28.97%). Incidents of narrowing of root canal and deviation of mandibular canal were found to be almost the same (11.90%). Also, deflection of roots and interruption of white line found to be of the same level of occurrence (9.52%). Dark and bifid root apex was the least common radiographic finding (2.38%). Darkening of root was again the most common finding on CT (38.10%), followed by narrowing of apexes. They concluded that the spiral CT image provides a unique opportunity to determine the exact position of impacted mandibular third molar and their relationship to

adjacent structure in all three planes. Computed tomography is highly capable in depicting the relationship of mandibular third molar with inferior alveolar nerve canal before treatment and accurate appraisal of the several aspects can be made regarding prognosis.

Yabroudi F, Sindet Pedersen S (2012)[34] conducted a study to assess the relationship between the mandibular third molar and the mandibular canal using cone-beam computed tomography (CBCT) with coronal and sagittal radiographic sections before surgery. Forty-seven mandibular third molars in 30 patients, identified as being in close proximity to the mandibular canal on panoramic radiographs, were further evaluated with CBCT. Their results showed that the mandibular canal was positioned buccally in 17.02% of cases, inferiorly in 44.68%, lingually in 23.4%, and between the roots in 14.89%. In 12 cases, no cortical bone separated the mandibular canal from the tooth root. CBCT provided more precise information on cortical bone presence than panoramic radiography. They concluded in their study that CBCT was more accurate in assessing the relationship between the mandibular canal and third molar roots and should be used when panoramic images show superimposition or close proximity of the roots to the canal.

Sanmartí-Garcia G, Valmaseda Castellón E, Gay-Escoda C (2012)[35] conducted a study to assess the utility of computed tomography (CT) in preventing inferior alveolar nerve (IAN) injury owing to lower third molar extraction in close relation to the IAN on orthopantomogram. In their study, 150 lower third molar extractions were performed. Patients were divided into 2 groups: the CT group underwent panoramic radiography and mandibular CT, and the control group underwent only panoramic radiography. Their results revealed that six extractions (4%) in the control group and 15 (10%) in the CT group resulted in IAN impairment. Logistic regression models did not show that undergoing CT decreased the risk of IAN injury from lower third molar extraction. They concluded that patient age and positive radiographic signs (darkening of the root and narrowing of the inferior alveolar canal) were associated with more requests for CT scanning. CT does not seem to significantly decrease the risk of producing IAN injury.

Neves FS, Souza TC, Almeida SM et al (2012)[11] performed a study on 72 individuals (142 mandibular third molars) who underwent pre-operative radiographic evaluation before extraction of impacted mandibular third molars. On panoramic radiographs, the most common signs of corticalization (darkening of roots, diversion of mandibular canal, narrowing of mandibular canal, and interruption of white line of canal and the presence or absence of corticalization between the mandibular third molar and the mandibular canal on CBCT images

were evaluated. Darkening of roots and interruption of the white line associated with the absence of corticalization between the mandibular third molar and the mandibular canal on CBCT images were statistically significant, both as isolated findings (p= 0.0001 and $p=0$.0006 respectively) and in association (p=0.002). No statistically significant association was observed for the other panoramic radiographic findings, either individually or in association (p >0.05). Darkening of roots and interruption of the white line observed on panoramic radiographs, both as isolated findings and in association, were effective in determining the risk relationship between the tooth roots and the mandibular canal, requiring three-dimensional evaluation of the case.

Deshpande P, V Guledgud M, Patil K (2013)[36] conducted a study to assess the proximity of impacted mandibular third molars with the inferior alveolar canal and identified reliable radiographic risk predictor signs on panoramic radiographs. Their study, included 68 impacted third molars in 64 subjects, with 40 (58.8%) on the right side and 28 (41.2%) on the left. Impaction types included in their study were mesio-angular (42.6%), horizontal (33.8%), vertical (19.1%), and disto-angular (4.4%). They found that the correlation between surgical and radiographic findings revealed that 9 out of 36 positive cases and 1 out of 32 negative cases were close to the inferior alveolar canal, with statistical significance. Among the seven evaluated radiographic signs, interruption of the white line was the most significant and reliable predictor of close proximity to the canal, observed in 7 of 10 surgically confirmed cases. Additionally, the darkening of roots, interruption of the white line, and diversion of the canal were associated with a higher risk of inferior alveolar nerve injury. They concluded that panoramic radiographs are effective in assessing the proximity of impacted third molars to the inferior alveolar canal, with mesio-angular impactions being the most common and most closely related to the canal.

Hasegawa T, Ri S, Shigeta T et al (2013)[37] conducted a study to investigate the relationships among risk factors for inferior alveolar nerve injury (IANI) and compared preoperative imaging findings between panoramic radiographs and computed tomography (CT) using univariate and multivariate analyses. Their results showed that the incidence of IANI was significantly higher in cases where the white line of the inferior alveolar canal was lost or the canal was diverted on panoramic radiographs. The most frequently observed panoramic sign indicating root proximity to the inferior alveolar nerve (IAN) was type 1, found in 173 of 440 teeth (39.3%), while type 5 was the least common, observed in 26 of 440 teeth (5.9%). Cases classified as type 1 had a significantly higher risk of IANI compared to other classifications. However, multivariate analysis did not show significant differences in patients without canal

diversion. Notably, panoramic radiography findings were inconsistent with CT findings in 62.5% of cases (275 teeth), suggesting that panoramic radiographs alone may not provide sufficiently reliable imaging for predicting nerve injury. They concluded that when panoramic images suggest a close relationship between an impacted third molar and the mandibular canal, CT should be performed for a more accurate assessment.

Hauge Matzen L, Christensen J, Hintze H et al (2013)[38] conducted a study to compare the diagnostic accuracy of panoramic imaging, stereo-scanography, and cone-beam computed tomography (CBCT) in assessing mandibular third molars. A total of 112 patients (147 mandibular third molars) underwent radiographic evaluations using these three imaging modalities, with intraoperative and postoperative findings serving as the reference standard. Their results revealed no significant differences among the three techniques in evaluating tooth angulation, root morphology, and the number of roots. However, CBCT demonstrated superior accuracy over stereo-scanography in detecting root bending in the bucco-lingual plane. Additionally, CBCT exhibited higher sensitivity than panoramic imaging in identifying direct contact between the roots and the mandibular canal. In contrast, panoramic imaging and CBCT had greater specificity than stereo-scanography for confirming the absence of direct root contact with the mandibular canal. Their study concluded that while all three imaging modalities were equally effective for assessing tooth angulation and root morphology, CBCT provided enhanced accuracy for evaluating root bending and direct root contact with the mandibular canal.

Shahidi S, Zamiri B, Bronoosh P (2013)[39] conducted a study to evaluate the reliability of panoramic radiographic signs in identifying the relationship between the roots of mandibular third molars and the inferior alveolar canal (IAC), and compared these signs with findings from cone beam computed tomography (CBCT). They included in their study a total of 132 impacted mandibular third molars were assessed using CBCT imaging to determine the relationship between the tooth roots and the canals. The CBCT results were then compared to the corresponding panoramic radiographs to evaluate the accuracy of panoramic signs. To establish the diagnostic criteria for the panoramic images, logistic regression analysis was employed. Among the various panoramic radiographic signs, the most commonly observed indicator of a potential association between the tooth root and the canal was the loss of the cortical line (with a sensitivity of 79.31%). In their study, they found that in cases where the loss of the cortical line or root darkening was visible on the panoramic radiographs, there was a confirmed contact between the tooth and the canal on the CBCT images. They concluded that certain panoramic radiographic signs, specifically root darkening and the loss of the

cortical line, are highly suggestive of a potential risk for inferior alveolar nerve (IAN) injury during third molar extraction. These signs can help clinicians assess the likelihood of nerve involvement and, when observed, may warrant further investigation with advanced imaging techniques like CBCT to reduce the risk of nerve damage.

Kim HG, Lee JH (2014)[40] conducted a study to evaluate cone-beam computed tomography (CBCT) images to categorize the relationships between the mandibular canal and the roots and investigated the prevalence of nerve damage. Through CBCT images, contact and three-dimensional positional relationships between the roots of the mandibular third molar and the mandibular canal were investigated. Their results reported that when the mandibular third molar and the mandibular canal were shown to have direct contact in CBCT images, the prevalence of nerve damage was higher than in other cases. Also, in cases where the mandibular canal was horizontally lingual to the mandibular third molar and the mandibular canal was vertically at the cervical level of the mandibular third molar, the prevalence of nerve damage was higher than in opposite cases. The percentage of mandibular canal contact with the roots of the mandibular third molar was higher when the mandibular canal was horizontally lingual to the mandibular third molar. Finally, the prevalence of nerve damage was higher when the diameter of the mandibular canal lumen suddenly decreased at the contact area between the mandibular canal and the roots, as shown in CBCT images. They concluded that the three-dimensional relationship of the mandibular third molar and the mandibular canal can help predict nerve damage and can guide patient expectations of the possibility and extent of nerve damage.

Pathak S, Mishra N, Rastogi MK et al (2014)[6] conducted a study to review seven radiographic findings related to the proximity of mandibular third molar roots to the inferior alveolar nerve (IAN) as observed on orthopantomogram (OPG) images. They aimed to establish a relationship between these radiographic variables and the occurrence of postoperative paresthesia. A total of 100 impacted teeth requiring surgical extraction were included in their study, with 29 females and 71 males. Their findings revealed that certain radiographic signs, such as narrowing of the canal and darkening of the roots, showed no statistically significant correlation with the development of postoperative paresthesia. However, their study highlighted the importance of orthopantomogram as a useful diagnostic tool in conventional radiography for assessing potential IAN injury. Additionally, specific radiographic features of the mandibular third molar and inferior alveolar canal—such as root grooving, hooked roots, bifid roots, and obliteration of the white line—were found to have significant predictive value for postoperative IAN paresthesia. They concluded that these

features could be used to better assess the risk of nerve injury during extraction. In cases where the diagnosis remains unclear, the study recommended opting for more advanced imaging techniques for a more comprehensive evaluation.

Guerrero ME, Botetano R, Beltran J et al (2014)[41] conducted a study to compare surgical complications and dysesthesia of IAN after impacted third molar extractions using panoramic radiography (PAN) and CBCT as imaging modalities during the preoperative diagnosis. Their secondary objective was to compare the reliability of CBCT with that of PAN in preoperative radiographic determination of the position of the third molar, number of roots, and apical divergence of the root. Their study sample consisted of impacted third molars from 256 patients with a close relation to the inferior alveolar nerve (IAN). Their results revealed that two extractions (1.5 %) in the CBCT group and five (3.8 %) in the PAN group resulted in IAN sensory disturbance. Logistic regression models did not show that CBCT modality decreased postoperative complications following surgical removal of impacted third molars. Yet, CBCT revealed the number of roots and apical divergence of the roots more reliably than panoramic radiographs. They concluded that CBCT was not better than panoramic radiography in predicting postoperative complications for moderate-risk cases of impacted third mandibular molars. Nonetheless, a CBCT buccolingual view can better confirm the number of roots and root morphology of the third molar than PAN. For management of postoperative complications for moderate-risk cases of impacted mandibular third molars, careful preoperative radiographic planning followed by an atraumatic surgical approach seems to be valuable, irrespective of the 2D or 3D nature of the preoperative images.

Peker I, Sarikir C, Alkurt MT et al (2014)[42] conducted a retrospective study to evaluate the correlation between cone-beam computed tomography (CBCT) and digital panoramic radiography (DPR) findings in preoperative examination of IMTM (impacted mandibular third molar). They included 298 teeth in 191 individuals in their study. In DPR images they evaluated the number of roots of the IMTM and the most common radiographic findings indicating a relationship between the IAC and the IMTM (darkening of the roots, diversion of the IAC, narrowing of the IAC and interruption of the white line).In CBCT image they evaluated relationship between the inferior alveolar canal (IAC) and the IMTM (buccal, lingual, interradicular or inferior), the position of the IMTM with respect to the IAC (contact, no contact), the morphologic shape of the mandible in the IMTM region (round, lingual extended, lingual concave), the type of IMTM (vertical, horizontal or angular) and the number of roots of the IMTM. They found significant difference in number of rootsdetected

on DPR versus CBCT image. There was a significant association between the type of IMTM and the morphologic shape of the mandible on CBCT images. Darkening of the roots and interruptionof the white line on DPR images were significantly associated with the presence of contact between the IMTM and the IAC on CBCT images. They concluded Panoramic radiography is inadequate, whereas CBCT is useful to detect multiple roots of IMTM. When darkening of the roots and interruption of the white line are observed on panoramic images, there is increased likelihood of contact between the IMTM and the IAC.

Sarikov R, Juodzbalys G (2014)[43] systematically reviewed the comprehensive overview of literature data about injury to the inferior alveolar nerve after lower third molar extraction to discover the prevalence of injury, the risk factors, recovery rates, and alternative methods of treatment. Their literature review revealed that Inferior alveolar nerve paresthesia occurs widely from 0.35% to 8.4%. With regard to the inferior alveolar nerve, the factors associated with a significantly higher incidence of paresthesia includes patients over the age of 24 years old, with horizontal impactions, close radiographic proximity to the mandibular canal, and treatment by inexperienced surgeons. To reduce the neurological risks, alternative strategies might be used like coronectomy and orthodontic extraction techniques. They found that injury to the inferior alveolar nerve is usually not permanent and has a good likelihood of regenerating over time, and most of the injuries are healed after 6 months.

Maglione M, Costantinides F, Bazzocchi G (2015)[44] conducted a study to introduce a new radiological classification that could be normally used in clinical practice to assess the relationship between an impacted third molar and mandibular canal on cone beam CT (CBCT) images. CBCT images of 80 patients (133 mandibular third molars) were independently studied. Eight different classes were proposed (classes 0-7) and six of them (classes 1-6) were subdivided into two subtypes (subtypes A-B). The distribution of classes showed a prevalence of buccal or apical course of the mandibular canal followed by lingual position and inter-radicular one. No differences have resulted in terms of anatomic relationship between males and females apart from a higher risk of real contact without corticalization of the canal when the IAN had a lingual course for the female group. Younger patients showed an increased rate of direct contact with a reduced calibre of the canal and/or without corticalization. They concluded that the use of this classification could be a valid support in clinical practice to obtain a common language among operators to define the possible relationships between an impacted third molar and the mandibular canal on CBCT images.

Lee B, Park Y, Ahn J, Chun J et al (2015)[45] conducted a study to evaluate the benefits of 3D-CT in preventing inferior alveolar nerve (IAN) damage during mandibular third molar

extractions. Cases were classified based on panoramic radiography findings and whether 3D-CT was used. IAN damage symptoms were assessed using a touch-recognition test. Their results showed hypoesthesia in affected cases but no anesthesia. Among 32 cases of IAN damage, 65.6% were right-sided and 34.4% were left-sided. The mandibular third molar roots were buccal (20.1%), middle (25.2%), or lingual (54.7%) relative to the inferior alveolar canal (IAC). No significant difference in IAN injury rates was found between groups. They concluded that 3D-CT is useful for evaluating molar-IAC proximity and aiding in IAN damage prevention.

Liu W, Yin W, Zhang R, Li J et al (2015)[5] conducted a study to evaluate the predictive value of panoramic radiography on inferior alveolar nerve (IAN) injury after extraction of the mandibular third molar. The effect size of pooled sensitivity, specificity, positive likelihood ratios (PLR), negative likelihood ratios (NLR) and diagnostic odds ratio (DOR) with their 95% confidence intervals (CI) were statistically analyzed. Their results revealed that the pooled estimates of sensitivity and specificity were 0.56 (95% CI: 0.50-0.61) and 0.86 (95% CI: 0.84-0.87), respectively. The overall PLR was 3.46 (95% CI: 2.02-5.92) and overall NLR was 0.58 (95% CI: 0.45-0.73). The pooled estimate of DOR was 6.49 (95% CI: 2.92-14.44). The area under the summary receiver operating characteristic curve was 0.7143 ± 0.0604. They concluded that the meta-analysis indicated that interpretation of panoramic radiography based on darkening of the root had a high specificity in predicting IAN injury after mandibular third molar extraction. However, the ability of the panoramic radiography marker to detect true positive IAN injury was not satisfactory.

Akter M, Rahman QB, Uddin MW et al (2016)[46] conducted a study to evaluate the proximity and relationship between impacted mandibular third molars and the inferior alveolar canal (IAC) using orthopantomogram (OPG) and cone-beam computed tomography (CBCT). Sixty impacted third molars with close proximity to the IAC were included, with CBCT used for precise localization. Their results showed variations in root positioning relative to the IAC, with mesio-angular impactions having the most significant CBCT-confirmed contact. They concluded that CBCT was found to be essential for accurately assessing third molar-IAC proximity beyond OPG findings, supporting its use in preoperative planning for third molar extractions.

Kamadjaja DB, Asmara D et al (2016)[47] conducted a study to determine whether there was correlation between Rood and Shehab's radiographic features and the incidence of inferior alveolar nerve paraesthesia following odontectomy of lower third molar. The case and non-case groups were assigned based on the presence of paraesthesia and non-paraesthesia of

inferior alveolar nerves, respectively. Based on Rood and Shehab's category, the samples collected were then classified into two groups, those whose relationship matched and did not match with the category, respectively. Data were analyzed using Chi-square correlation test. Their results showed that the highest rate of appearance of Rood and Shehab's radiographic features was relation 'A' (12.50%) followed by relation 'B' and 'G' (7.50%) while the lowest rate of appearance was relation 'D' and 'F' (2.50%). However, the highest rate of appearance among total samples was the relation "others" (60%) which was the relation other than those of Rood and Shehab's category. Their result also showed that both relation 'A' and 'B' had the highest incidence rate (13.3%) of paraesthesia within Rood and Shehab category, while relation "others" which was the relation other than those of Rood and Shehab's category showed the highest incidence rate (66.67%) among total samples. They concluded that there was no correlation between Rood and Shehab's radiographic features and the incidence of paraesthesia of inferior alveolar nerve following odontectomy of lower third molars.

Mukherjee S, Vikraman B, Sankar D et al (2016)[2] conducted a study to evaluate the fate of the root (resorbed, exfoliated, covered by bone) after coronectomy or intentional root retention of impacted mandibular third molars in patients with high risk for inferior alveolar nerve damage as evaluated by the intra oral periapical radiograph. Twenty impacted mandibular third molar teeth, in 18 patients with high risk of injury to IAN based on Rood's Criteria in an intra oral periapical radiographic examination, between the age group of 18 to 40 years, were included in their study. Pederson Difficulty Index and Winter's Classification of impacted tooth was recorded. Coronectomy was done at the cemento enamel junction leaving the roots 2-3mm below the alveolar crest and primary closure was done. Their results revealed that none of the patients had IAN injury and none required second surgical removal. There was no incidence of post-operative infection and none required second surgical intervention. However, two of their patients had failed coronectomy (10%) due to mobilization of roots intra operatively and the roots were removed. One patient developed profuse bleeding intra-operatively in the failed coronectomy case. One patient had temporary lingual nerve paresthesia. They concluded that Coronectomy procedure is effective in controlling inferior alveolar nerve injury following third molar surgery, in radiographically evaluated high risk cases and it has very low incidence of complications.

Kundoor VKR, Maloth KN et al (2017)[21] performed a study on samples consisted of 60 IMTM (impacted mandibular third molar) from 40 patients (16 males and 24 females) with a mean age of 24years who showed a superimposed relationship of the mandibular canal and

IMTM on panoramic radiograph and were referred to CBCT examination center prior to IMTM extraction. On panoramic radiographs, the relationship between IMTM and mandibular canal was evaluated according to the criteria established by Rood and Shehab. In this study, they examined three panoramic signs such as darkening of the root, interruption of the mandibular canal, and contact of canal to root. Diversion and narrowing of the canal were not evaluated because they were rarely observed in a superimposed relationship between the third molar and the mandibular canal. In this study they found that in two-dimensional (OPG) imaging, absence of the cortical bone of the mandibular canal is not clearly evident, and it is difficult to determine whether its course is buccal or lingual to the roots or betweenthe roots. They concluded that more advanced 3D imaging techniques CBCT are required to clarify the accurate anatomical relationships between IAN and mandibular third molar prior to surgical extraction so as to prevent IAN injury.

Korkmaz YT, Kayıpmaz S, Senel FC et al (2017)[48] conducted a study to evaluate the efficacy of additional cone beam computed tomography (CBCT) imaging in reducing the risk of inferior alveolar nerve (IAN) injury during third molar removal in patients identified as high-risk. Additionally, their study aimed to assess surgical outcomes associated with the use of CBCT compared to conventional panoramic radiography (PAN). Their study sample consisted of 122 patients, encompassing 139 third molars, with ages ranging from 18 to 48 years. Patients were divided into two groups: one undergoing preoperative CBCT imaging and the other relying solely on PAN. The risk of IAN injury was analyzed postoperatively at multiple intervals, including 7 days and 6 months after surgery. They found that at the 7-day postoperative mark, temporary IAN injury was observed in 3 cases (4.2%) within the CBCT group, compared to 11 cases (16.4%) in the PAN group, indicating a notable reduction in early nerve injury among patients evaluated with CBCT. However, at the 6-month follow-up, none of the patients in either group demonstrated signs of permanent IAN injury, highlighting similar long-term outcomes for both imaging modalities. They concluded that while CBCT imaging was not superior to PAN in preventing permanent IAN injuries in the long term, its use appeared to significantly lower the incidence of temporary IAN injuries during the early postoperative period. Furthermore, the use of CBCT may enhance surgical planning and outcomes in high-risk cases, offering a potential benefit in select patient populations.

Su N, van Wijk A, Berkhout E et al (2017)[16] conducted a study to assess the added value of panoramic radiography in predicting postoperative injury of the inferior alveolar nerve (IAN) in the decision-making before mandibular third molar (MM3) surgery. MEDLINE and EMBASE were searched electronically to identify the diagnostic accuracy of studies that had

assessed the predictive value of 7 panoramic radiographic signs, including root-related signs (darkening of the root, deflection of the root, narrowing of the root, and dark and bifid apex of the root) and canal-related signs (interruption of the white line of the canal, diversion of the canal, and narrowing of the canal) for IAN injury after MM3 surgery. Their results revealed the pooled positive predictive value (PPV) and negative predictive value (NPV) ranged from 7.5 to 26.6% and 95.9 to 97.7%, respectively. The added value of a positive sign for ruling in an IAN injury (PPV minus the prior probability) ranged from 3.4 to 22.2%. The added value of a negative sign for ruling out an IAN injury (NPV minus [1 minus the prior probability]) ranged from 0.1 to 2.2%. They concluded that for all 7 signs, the added value of panoramic radiography is too low to consider it appropriate for ruling out postoperative IAN in the decision-making before MM3 surgery. The added value of panoramic radiography for determining the presence of diversion of the canal, interruption of the white line of the canal, and darkening of the root can be considered.

Hashemzehi H, Moaddabi A, Hasheminia D et al (2018)[15] performed a study to compare OPG and CBCT for assessing the relationship between impacted mandibular third molar and inferior alveolar nerve. 60 patients in the age group of 18–30 years with impacted mandibular third molar (IMTM) were included in the study. Panoramic radiographs were used to assess the relationship between IAN and third molar through Shehab & Rood criteria. Nerve proximity of the third molar, both when in contact and separated, was determined using CBCT. Of 60 impacted third molars, 33 teeth showed contact between the tooth and the nerve. Panoramic radiograph findings of 60 IMTM (impacted mandibular third molar) indicated darkening of the root in 23 cases (38.3%), deflection of the root in 19 cases (31.7%), narrowing of the canal in 11 cases (18.3%), interruption ofwhite line in 5 cases (8.4%), and diversion of the canal in 2 cases (3.3%). The CBCT findings indicated that among the 60 IMTM there was a contact between the third molar root and the IAC in 35 cases (58.3%) and in 25 cases (41.7%) there was no contact between the third molar root and the IAC.

Ghai S, Choudhury S (2018)[9] conducted a study to analyze the relationship between mandibular third molars and the inferior alveolar canal (IAC) using panoramic radiography (PAN) and cone beam CT (CBCT) while assessing radiographic predictors of IAN exposure and postoperative paresthesia. PAN and CBCT findings of 53 impacted third molars were evaluated using a modified Rood and Shehab Criteria. The most common PAN feature was darkening of roots (DR) with interruption of the white line (IWL) (35.86%), while CBCT most frequently showed thinning of the lingual cortex (81.14%). IAC was most often located inferiorly (47.16%) or buccally (26.41%). IAN exposure occurred in 7.55% of cases, with

3.77% developing paresthesia. They concluded that DR with deflection (DEFR) or IWL in PAN and inter-radicular IAC with lingual cortex thinning in CBCT are strong predictors of nerve exposure and paresthesia.

Wang D, Lin T, Wang Y et al (2018)[49] conducted a study to identify the radiographic signs between impacted third molar root and inferior alveolar canal (IAC) on cone-beam CT (CBCT) images as risk factors and prognostic predictors associated with inferior alveolar nerve (IAN) damage following tooth removal. The neurosensory function of the lower lip and chin was subjectively evaluated and assessed by neurosensory tests before and after surgery. The preoperative CBCT data were retrieved and analyzed to identify the radiographic signs associated with postoperative IAN injury. Following extraction, 42 patients reported paresthesia in the chin and lower lip region, then received oral administration of mecobalamin for 8 weeks. Several patients recovered within 4 weeks and had normal sensory functions. Until the last follow-up at least 6 months after extraction, paresthesia or numbness was identified in 27 patients with 34 sides. They concluded that that radiographic sign, including direct contact between IAC and root, buccal/lingual IAC position relative to root, teardrop/dumbbell shape, and cortication absence of the IAC on presurgical CBCT images were associated with high risk of IAN injury and postoperative neurosensory disturbance.

Pandeya R, Ravindran C, Pandiyan D et al (2018)[50] conducted a study to evaluate Roods and Shehab criteria if one or more radiological signs are present in orthopantomogram and position of the mandibular canal in relation to the third molar apices using cone beam computed tomography (CBCT). A total of 25 orthopantomogram radiographs exhibiting close relationship between mandibular third molar apices and mandibular canal according to Roods and Shehab criteria were accessed for cortical integrity along with position of the canal using CBCT. Their results revealed that a single radiographic sign was seen in 81% of the cases and two or more signs were present in 19% of the cases. The most commonly seen signs were darkening of root followed by interruption of the white line of the canal and deflection of the root. The position of the IAN when assessed using CBCT in relation to root apex of third molar was found buccal in 61.7% of the cases followed by inferior in 23.4% of the cases**.** They concluded that CBCT has advantages of visualizing the exact topographic relationship of the mandibular canal to the tooth structure. This helps in planning the surgical procedure and will allow planned guttering of the bone and odontotomy to facilitate tooth removal without causing pressure damage or transection of the IAN.

Azahar FA, Oo AL, Nambiar P et al (2018)[51] conducted a study to investigate the diagnostic accuracy of the dental panoramic image compared to cone-beam computed tomography

(CBCT) in predicting the inferior alveolar nerve (IAN) exposure during impacted third molar extraction. Thirty-two patients showed signs of proximity of the roots of the third molars to the mandibular canal from the dental panoramic image, were selected for CBCT. Their results showed no significant difference for the prediction on nerve exposure and injury from the dental panoramic image, however, showed a significant difference for the cone-beam computed tomography. The prevalence of contact between the third molar to the inferior alveolar canal (IAC) were 96.8% with a significant finding p = 0.002. There was a significant difference in the loss of cortex in predicting nerve exposure. Clinically, three patients had nerve exposure and two patients had neurosensory disturbances. They concluded that dental panoramic images were still valuable for predicting the proximity of the third molar to the inferior alveolar canal. Nevertheless, CBCT had the best precision in localizing the close contact between the third molar and the inferior alveolar canal. They found that there were no significant finding from the CBCT for the incidence of the inferior alveolar nerve exposure and injury. However, it was noted to be accurate in predicting the IAN exposure. All these findings proved that cone-beam computed tomography contributed in the surgical plan, reduced operative time, and patient morbidity.

Salam S, Rehman AZU, Alam S et al (2020)[52] conducted a study to evaluate the position of the inferior alveolar nerve (IAN) relative to the mandibular third molar using CBCT. They found that the IAN was buccal in 47.1% of cases (27% with direct contact), lingual in 17.1% (41.6% with direct contact), inferior in 27.1% (57.8% with direct contact), and interradicular in 8.6% (100% with direct contact). The interradicular position showed a statistically significant association with direct contact. They concluded that CBCT is a precise tool for preoperative assessment, aiding in surgical planning for mandibular third molar extraction.

Patel PS, Shah JS, Dudhia BB et al (2020)[1] Performed a study to analyze radiographic signs of close relationships between impacted mandibular third molars (IMTM) and the inferior alveolar nerve (IAN) canal using OPG and CBCT in 120 individuals (200 IMTM) before surgical extraction. OPG evaluations included Rood and Shehab's signs, Winter's classification, and Pell & Gregory's depth assessment, while CBCT assessed corticalization and buccal/lingual cortex status. They found significant associations between 'no relation' and 'superimposition' on OPG and the presence of corticalization on CBCT, as well as 'mesio-angular' and 'vertical' positions with Class 1A impaction. They concluded that certain OPG signs (interruption of white line, root darkening, canal darkening, root deflection, and

canal narrowing or diversion) indicate the need for CBCT to minimize postoperative neurological complications.

Verma A, Verma S, Dhankhar A (2021)[53] conducted a study to evaluate radiological features of impacted mandibular third molars and their relationship with the inferior alveolar nerve (IAN) using panoramic radiography and CBCT to identify predictive criteria for IAN injury during extraction. All patients undergoing lower third molar removal were included in the study, with preoperative panoramic and CBCT imaging. Postoperative nerve injuries were assessed at 15 days and 1 month. They found that 11.4% of participants experienced IAN injury, all associated with bony impactions, while soft tissue impactions had no neurological symptoms. Fisher's exact test showed a significant association ($p < 0.05$) between IAN injury and nerve exposure, panoramic radiographic signs, impaction level, and nerve approximation in CBCT, but no correlation with age, sex, or impaction site. They concluded that CBCT more accurately predicts IAN injury risk than panoramic radiography.

Zhang J, Gao X, Zhang W (2022)[54] conducted a study to assess the accuracy of panoramic radiography (PAN) compared to CBCT in evaluating the anatomical relationship between the mandibular third molar (MTM) and inferior alveolar nerve (IAN) canal. In their study, they analyzed 953 MTMs from 544 patients, identifying 196 cases of IAN canal wall absence and 757 cases of canal wall presence on CBCT. Seven radiographic signs were observed on PAN, and mandibular canal integrity was evaluated using CBCT 3D imaging. They found a statistically significant correlation between the number of specific PAN imaging signs and IAN canal defects detected on CBCT. Pell & Gregory (P&G) Class II and III impactions had a higher probability of mandibular canal cortical defects than Class I. They concluded that P&G classification in the mesiodistal direction is a more critical risk factor for IAN canal defects than its vertical classification, emphasizing the importance of CBCT for preoperative assessment.

Bhardwaj P, Bhardwaj Y, Ram R et al (2022)[55] conducted a study to evaluate the correlation between risk factors on orthopantomograms (OPG) and cortical integrity of the inferior alveolar canal (IAC) on CBCT and their influence on nerve exposure and postoperative neurosensory deficits in impacted mandibular third molar (M3M) surgery. 200 patients were initially assessed in their study using OPG, with 75 high-risk cases further examined using CBCT to analyze cortical boundary integrity and canal position (buccal, lingual, inferior, or interradicular). They found that cortical boundary disruption and an interradicular or lingual IAN position strongly predicted intraoperative nerve exposure.

However, nerve exposure did not always result in neurosensory deficits, as factors like bone density, patient demographics, surgeon expertise, tissue damage, and postoperative edema also played a role. Their study emphasized the multifactorial nature of nerve injury risk in third molar extractions.

MATERIALS AND METHODS

MATERIALS:

SOURCE OF DATA:

Patients between the age group of 18 to 60 years requiring surgical extraction of impacted third molars who presented to the Department of Oral and Maxillofacial Surgery at Santosh Dental College and Hospital in Ghaziabad and needed minor oral surgery to extract impacted mandibular third molars were chosen for the study. A pre-operative OPG and CBCT were taken for radiographic evaluation. All participants provided signed informed consent after receiving a brief explanation of the assessment procedure.

SAMPLE SIZE:

"A total of 35 individuals, comprising both males and females within the age range of 18 to 60 years, were enrolled in the study."

STUDY DESIGN:

This was a Prospective clinical study.

SELECTION CRITERIA

INCLUSION CRITERIA:

- Patients who were within the age range of 18-60 years.
- Patients who had an impacted wisdom tooth showing close proximity to the IAN canal on a two-dimensional radiograph, as per the Rood and Shehab classification.
- Patients who were medically fit (ASA 1 and ASA 2).

EXCLUSION CRITERIA:

- Patients who were not willing to comply with the study.
- Patients who had mandibular pathologies in close proximity to the IAN.
- Patients who had existing neurological deficits involving the IAN.
- ASA 3 and ASA 4 patients were excluded.

ARMAMENTARIUM

Fig.1: OPG machine

Digital OPG were acquired using an orthopantomography (Rays-Scan OPG 2D) machine that was standardized at 80kVp/15 mA with an exposure period of 13 sec. Data were evaluated using SMARTDENT-softwere.

Fig.2: CBCT machine

CBCT scans were acquired with a CBCT planmeca machine set at 85 kVp, 15 mA, and a scanning time of 36 sec for whole mouth and 19.96 sec for single quadrant. The canal was traced on the CBCT images, and the traced structure was then visualized in three dimensions across sagittal, coronal, and axial planes. This was done using a standard resolution setting with a voxel size of 0.25 mm, alongside an extended field of view mode measuring 5 x 5 mm.

Fig.3: TFT monitor (Romex software / Romexis)

CBCT data were evaluated using Romex software / Romexis. A 27-inch TFT monitor with a screen resolution of 1280 × 1024 pixels was used to display the radiographs.

Fig.4: Basic surgical kit for impaction surgery

Instrumentation for the surgical procedure:

- Mouth mirror
- Probe and explorer
- Towel clips
- Bard-Parker handle (3)
- Surgical blades (15)
- Periosteal elevators
- Austin retractor

- Cheek retractor
- Tongue depressor/retractor
- Suction tips
- Surgical handpiece and burs
- Tissue forceps (with or without teeth)
- Elevators (Coupland's, Cryer's, Warwick James, Howarth)
- Luxators
- Mandibular third molar extraction forceps
- Curettes
- Rongeurs
- Bone file
- Irrigation system (saline with syringe)
- Gauze packs
- Needle holder
- Suture cutting scissors
- Sutures (resorbable or non-resorbable like 3-0 silk or Vicryl)

METHODS:

STUDY DESIGN

A detailed case history was obtained and a thorough clinical examination was done. A pre-operative OPG and CBCT were taken for radiographic evaluation. PEDERSON Difficulty index assessment was performed (Table 1) and the impacted teeth were graded as "very difficult, moderately difficult, minimally difficult". The surgical procedure, potential complications, and the duration of the follow-up period were thoroughly explained to the patients. Informed consent was obtained from all individuals who agreed to participate in the study.

S.No	Classification	Difficulty index value
1.	**Angulation**	
	Mesio-angular	1
	Horizontal/Transverse	2
	Vertical	3
	Disto-angular	4
2.	**Depth**	
	Level A	1
	Level B	2
	Level C	3
3.	**Ramus relationship**	
	Class I	1
	Class II	2
	Class III	3

Difficulty index very difficult: 7-10, Moderately difficult: 5-7, Minimally difficult: 3-4

TABLE 1: PEDERSON DIFFICULTY INDEX

SURGICAL PROCEDURE:

- The patient was planned to undergo surgical removal of an impacted wisdom tooth using local anesthesia.
- Before surgery, patients were advised to rinse their mouth with a betadine gargle as an antiseptic mouthwash for 60 seconds.
- Extraoral and intraoral preparation was done, and the patient was draped in a sterile and aseptic manner.
- 2% lignocaine hydrochloride with adrenaline bitartrate was administered for classical inferior alveolar, lingual, and buccal nerve block.
- An appropriate incision (Ward's or Modified Ward's) was made to raise a mucoperiosteal flap, providing sufficient access to the impacted third molar.
- Bone guttering was performed under copious saline irrigation to facilitate tooth removal.
- The impacted tooth was extracted either in toto or with odontectomy, as required.
- The socket was debrided using betadine and saline, and any sharp bony prominences were smoothened.
- Hemostasis was achieved and wound closure was performed with a 3-0 silk suture.
- The patient was closely monitored intraoperatively for signs of nerve injury, such as excessive bleeding, severe pain, or direct exposure of the nerve.
- Postoperatively, neurosensory assessment of the inferior alveolar nerve (IAN) was conducted using:

    a) Two-point discrimination test
    b) Light touch test
    c) Pin-prick test
    d) Pressure application test

- Clinical outcomes of nerve exposure or injury were correlated with preoperative risk assessment based on 2D and 3D imaging.
- This correlation helped to evaluate the predictive accuracy of radiographic imaging in assessing nerve injury risk and guided future treatment planning.

CRITERIA FOR EVALUATION OF POSTOPERATIVE NEUROSENSORY ASSESSMENT

a) Two-point discrimination test

The patient was asked to indicate whether they felt one or two points as the caliper was gradually pressed across the skin or mucosa. They were instructed to raise their left hand whenever they perceived two distinct points from the caliper applied sequentially to the skin or mucosa. The minimum distance at which the patient correctly identified two points in five or six attempts was recorded for that specific area. If the patient responded incorrectly, the caliper was adjusted to a larger separation distance; if the response was correct, a smaller separation distance was used for the next trial.

b) Light touch test

This method was used to test tactile stimulation by gently touching the skin and assessing the patient's detection threshold. A cotton wisp was used to perform the test, with stimuli applied at random. The area of anesthesia was mapped by gradually moving outward in small steps until the patient perceived the stimulus.

c) Pin-prick test

In this test, a sharp dental probe was immediately pricked into the skin to measure the patient's pain perception. Each test region was poked three times on both sides, and the patient was asked if they detected a difference between the two. Pricking the mucosa, lip, and skin around the chin was used to assess sensation.

d) Pressure application test

The pressure sensation test is used to assess neurosensory deficits following lower third molar surgery. Using a blunt instrument, firm but non-painful pressure is applied to areas such as the lower lip, chin while the patient’s eyes are closed. The patient is asked to report the presence and intensity of the sensation compared to the unaffected side. Reduced or absent sensation indicates possible nerve injury.

REPRESENTATIVE CASES

Case-1:

Fig.5.1: Intra-oral pre-op photograph

Fig.5.2: Pre-operative OPG: Winters's classification- Mesio-angular impacted 48. Pell & Gregory's classification- Position A, Class II. Pederson difficulty index- 4 (slightly difficult). Rood and Shehab Criteria- Darkening of root, interruption of white line of canal, narrowing of the IAC

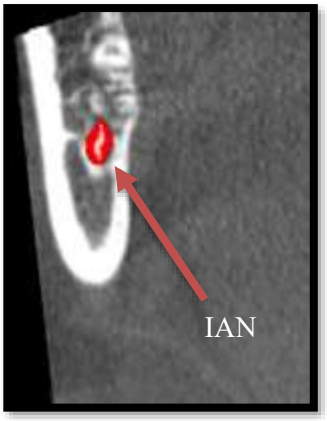


Fig.5.3: Pre-operative CBCT (Coronal section) reveals direct contact of IAC with the root apex of the third molar and also reveals thinning of the lingual cortical plate. Mesial and the distal roots are seen, which are separated and causing thinning and indentation of lingual cortex. Mesial root is bifurcated into two separate root apex at apical 1/3rd level.

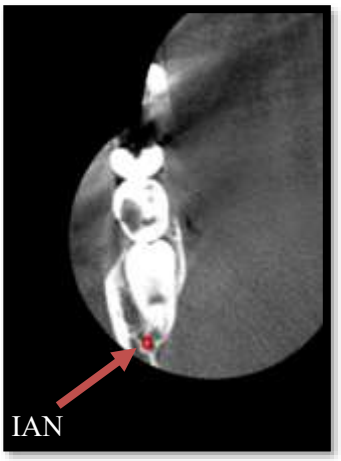


Fig.5.4: Pre-operative CBCT (Axial section) reveals type 2 morphologic shape of the bone in the third molar region and also reveals that the inferior alveolar canal courses inferiorly and buccally to the root apices, there is point contact of IAN canal with apical 1/3rd of mesial root. Evidence of decortication and clear compression of nerve (IAN).

Fig.5.5 Pre-operative CBCT (Sagittal section) reveals mesio-angular type of impaction of 48 and also reveals that the apical 1/3rd of the mesial root is abutting the IANC with mild narrowing of the IANC observed.

Intra-op

Fig.5.6: Modified Ward's incision

Fig.5.7: Extraction socket of 48

Fig.5.8: Extracted tooth 48

Case -2:

Fig.6.1: Intra-oral pre-op photograph

Fig.6.2: Pre-operative OPG: Winters's classification- Disto-angular 38. Pell and Gregory's classification- Position- B, Class II. Pederson difficulty index- 8. Rood and Shehab criteria- Darkening of root, Interruption of the canal.

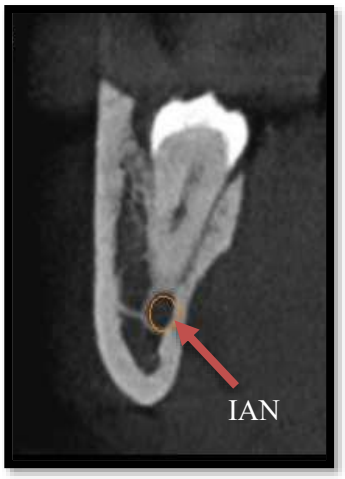


Fig.6.3: Pre-operative CBCT (Coronal Section) reveals direct contact of IAC with respect to the root apex of third molar and also reveals thinning of the lingual cortical plate. IAN courses in the lingual subcortical region caudal to root apices with indentation-impingement of the superior cortex.

Fig.6.4: Pre-operative CBCT (Axial section) reveals type 3 morphologic shape of the bone in the third molar region. Two roots (mesial and distal root) canal is placed lingual to the roots of third molar. IAN is running lingually to the distal root, there is direct contact of IAN with apical 1/3rd of distal root.

Fig.6.5: Pre-operative CBCT (Sagittal section) reveals disto-angular type of impaction of 38. IAN is running apically and lingually, there is direct contact of IAN with apical 1/3rd of distal root. Evidence of decortication and clear compression of nerve (IAN) towards the lingual cortex. Sagittal section reveals fusion of both mesial and distal roots.

Intra-op

Fig.6.6: Ward's incision

Fig.6.7: Extraction socket of 38

Fig.6.8: Extracted tooth 38

Case-3:

Fig.7.1: Intra-oral pre-op photograph

Fig.7.2: Pre-operative OPG: Winter's classification- Horizontally impacted 38. Pell & Gregory's classification- Position B, Class II. Pederson difficulty index- 6 (moderately difficult). Rood and Shehab criteria- Darkening of root, interruption of the white line of the canal, narrowing of canal

Fig.7.3: Pre-operative CBCT (Coronal section) reveals direct contact of IAC with the root apex of third molar and also reveals thinning of the lingual cortical plate. Tooth is oriented more towards the lingual cortical plate.

Fig.7.4: Pre-operative CBCT (Axial section) reveals type 2 morphologic shape of the bone in the third molar region. IAN is running lingually to the distal root, there is direct contact of IAN with apical 1/3rd of distal root. Evidence of decortication and clear compression of nerve (IAN) towards the lingual cortex.

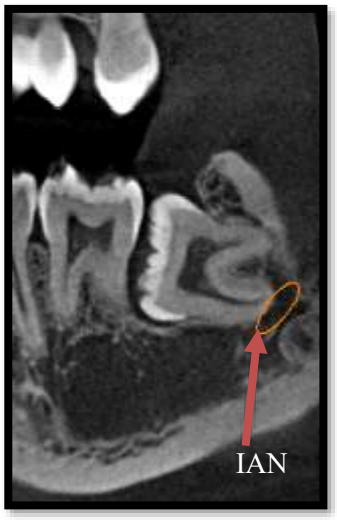


Fig.7.5: Pre-operative CBCT (Sagittal section) reveals horizontal type of impaction of 48. Tooth 38 shows two roots, mesial and distal with root formation complete. Sagittal section reveals that the apical 1/3rd of the mesial root is abutting the IANC with mild narrowing of the IANC observed.

Intra-op

Fig.7.6: Modified Ward's incision

Fig.7.7: Extraction socket of 38

Fig.7.8: Extracted tooth 38

Case-4:

Fig.8.1: Intra-oral pre-op photograph

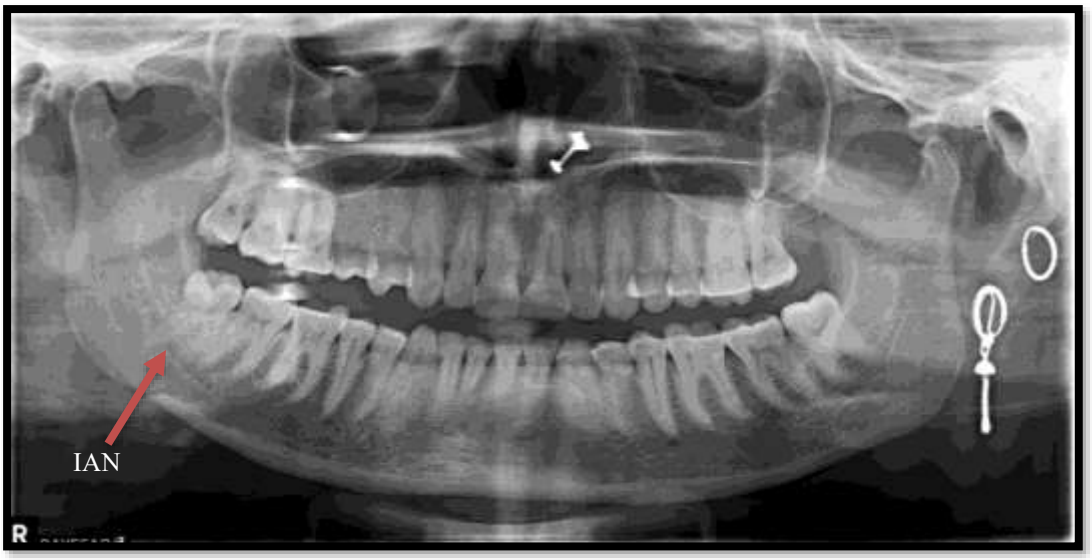


Fig.8.2: Pre-operative OPG: Winter's classification- Disto-angular 48. Pell and Gregory's classification- Position- A, Class II. Pederson's difficulty index- 7. Rood and Shehab criteria- Darkening of root, Deflection of root, interruption of the white line of the canal

Fig.8.3: Pre-operative CBCT (Coronal section) reveals direct contact of IAC with the root apex of third molar and also reveals thinning of the lingual cortical plate. Tooth is oriented more towards the lingual cortical plate.

Fig.8.4: Pre-operative CBCT (Axial section) reveals type 2 morphologic shape of the bone in the third molar region. Two mesial roots (mesio-buccal and mesio-lingual) and one distal root. Canal is placed lingual to the roots of third molar. IAN is running lingually to the distal root, there is direct contact of IAN with apical 1/3rd of distal root.

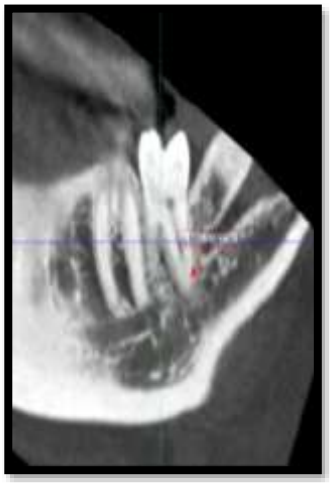


Fig.8.5: Pre-operative CBCT (Sagittal section) reveals disto-angular type of impaction of 48. IAN is running lingually to the distal root at apical 1/3rd level, there is direct contact of IAN with apical 1/3rd of distal root. Evidence of decortication and clear compression of nerve (IAN) towards the lingual cortex.

Intra-op

Fig.8.6: Ward's incision

Fig.8.7: Extraction Socket of 48

Fig.8.8: Extracted tooth 48

Fig.8.9 MAPPING OF NEURO-SENSORY DEFICIT (POST-OP DAY 1 TO POST-OP DAY 90)

Fig.8.9a: Post-op day 1

Fig.8.9b: Post-op day 7

Fig.8.9c: Post-op day 15

Fig.8.9d: Post-op day 30

Fig.8.9e: Post-op day 60

Fig.8.10f: Post-op day 90

Case-5:

Fig.9.1: *Intra-oral pre-op photograph*

Fig.9.2: Pre-operative OPG: Winter's classification- Mesio-angular impacted 38. Pell & Greogory's classification- Position B, Class II. Pederson difficulty index- 5 (moderately difficult). Rood & Shehab Criteria- Darkening of root, Narrowing of roots, Interruption of the white line of the canal

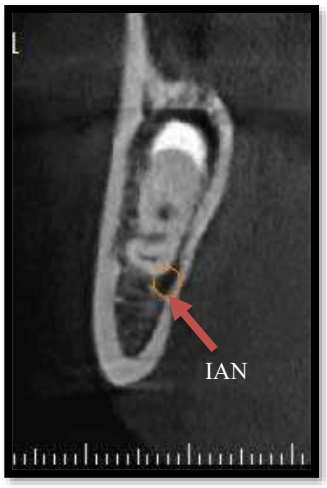


Fig.9.3: Pre-operative CBCT (Coronal section) reveals direct contact of IAC with the root apex of third molar and also reveals thinning of the cortical plate. Tooth is oriented more towards the lingual cortical plate.

Fig.9.4: Pre-operative CBCT (Axial section) reveals type 3 morphologic shape of the bone in the third molar region and also reveals direct contact of IAC with the root apex of third molar. Canal is placed lingual to the roots of third molar.

Fig.9.5: Pre-operative CBCT (Sagittal section) of third molar reveals mesio-angular type of impaction of 38. Mesial and distal roots (2 roots) are seen fused in the apical third.

Intra-op

Fig.9.6: Ward's incision

Fig.9.7: Extraction socket of 38

Fig.9.8: Extracted tooth 38

Case-6:

Fig.10.1: Intra-oral pre-op photograph

Fig.10.2: Pre-operative OPG: Winter's classification- Mesio-angular impacted 38. Pell & Greogory's classification- Position A, Class II. Pederson difficulty index- 4 (slightly difficult). Rood & Shehab Criteria- Darkening of root, Narrowing of canal, Dark and bifid apex

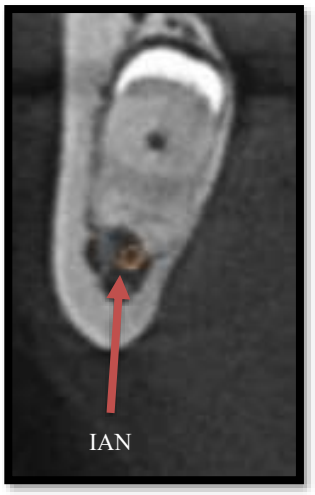


Fig.10.3: Pre-operative coronal section of CBCT reveals direct contact of IAC with the root apex of third molar and also reveals thinning of the lingual cortical plate.

Fig.10.4: Pre-operative axial section of CBCT reveals type 2 morphologic shape of the bone in the third molar region and also reveals direct contact of IAC with the root apex of third molar. IAN courses in inter-radicular region of DB-DL rootlets and MB-ML rootlets in apical area with indentation-impingement of superior cortex.

Fig.10.5: Pre-operative Sagittal section of CBCT reveals mesio-angular type of impaction of 38 and also reveals direct contact and compression of IAC with the root apex of third molar.

Intra-op

Fig.10.6: Modified Ward's incision

Fig.10.7: Socket of 38

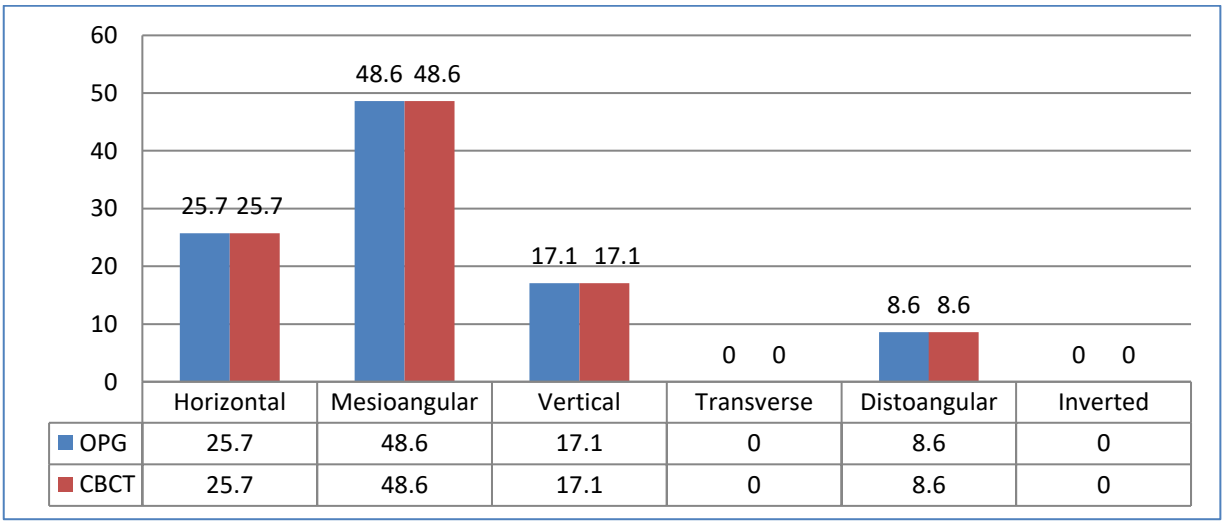
Fig.10.8: Extracted tooth 38

RESULTS

	Horizontal	Mesio-angular	Vertical	Transverse	Disto-angular	Inverted	P value
OPG	9	17	6	0	3	0	1.000(Non-Significant)
	25.7	48.6	17.1	0	8.6	0	
CBCT	9	17	6	0	3	0	
	25.7	48.6	17.1	0	8.6	0	

Table 2: Difference between the two imaging techniques (OPG and CBCT) in terms of classification distribution

The results of Winter's classification[56] for lower impacted third molars, as assessed through both OPG (Orthopantomogram) and CBCT imaging, show identical distribution across the different categories. The majority of impacted third molars were classified as mesio-angular (48.6%), followed by horizontal (25.7%) and vertical (17.1%). A smaller percentage of cases were classified as disto-angular (8.6%), with no cases identified as inverted in either imaging modality (Table 2 & Graph 1). The statistical analysis, indicated by the p-value of 1.000, reveals no significant difference between the two imaging techniques (OPG and CBCT) in terms of classification distribution, suggesting that both imaging methods provide similar results in assessing the angulation and position of lower impacted third molars.

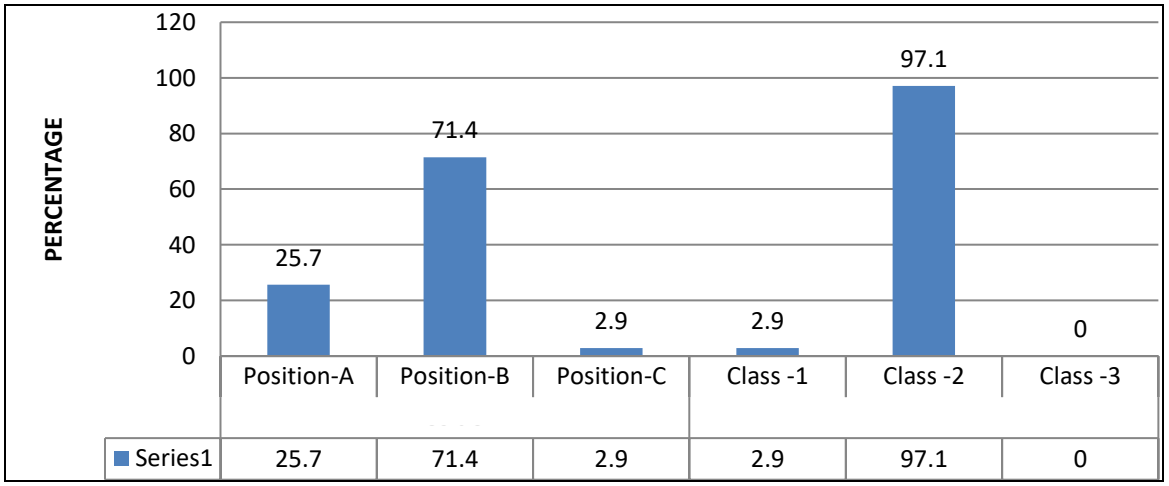


Graph 1: Difference between the two imaging techniques (OPG and CBCT) in terms of classification distribution

		N	Percentage
Position	Position-A	9	25.7
	Position-B	25	71.4
	Position-C	1	2.9
Class	Class -1	1	2.9
	Class -2	34	97.1
	Class -3	0	0

Table 3: Pell and Gregory's classification[57] for impacted mandibular third molars shows a distribution across the different positions and classes

The results of Pell and Gregory's classification[57] for lower impacted third molars show a distribution across the different Positions and Classes. In terms of Position**,** the majority of the cases were classified as Position-B (71.4%), followed by Position-A (25.7%), and a very small percentage of cases were classified as Position-C (2.9%). For the Class distribution, the majority of cases fell under Class-2 (97.1%), with a small proportion in Class-1 (2.9%). No cases were classified as Class-3 (Table 3 & Graph 2)**.** These findings indicate that the most common position for lower impacted third molars was Position B**,** and the most common class was Class 2**.**

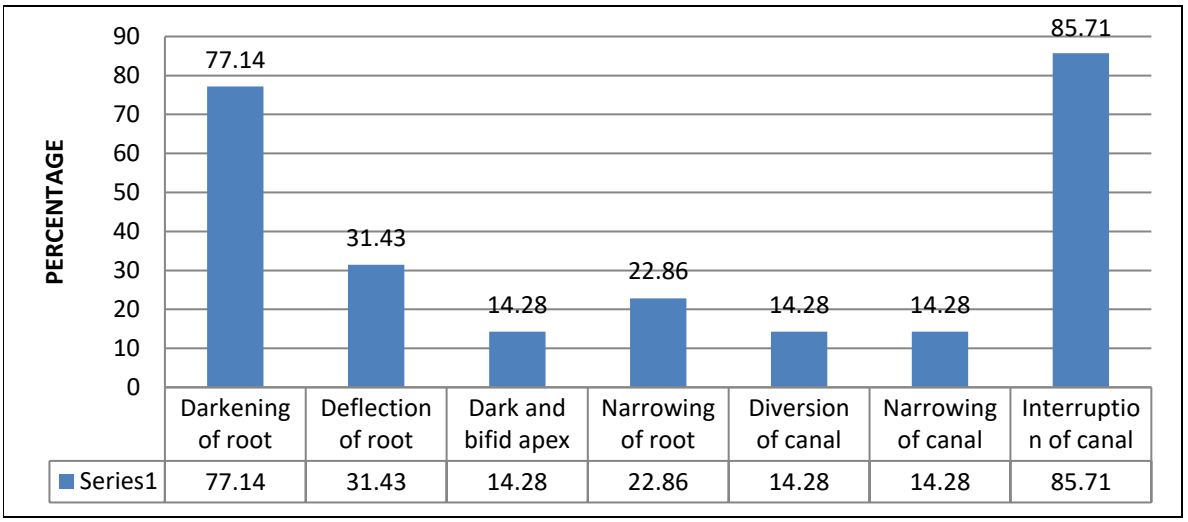


Graph 2: Pell and Gregory's classification for impacted mandibular third molars shows a distribution across the different positions and classes

	Present (No.)	Present (Percentage)
Darkening of root	27	77.14
Deflection of root	11	31.43
Dark and bifid apex	5	14.28
Narrowing of root	8	22.86
Diversion of canal	5	14.28
Narrowing of canal	5	14.28
Interruption of canal	30	85.71

Table 4: OPG evaluation based on seven radiographic signs (Rood and Shehab criteria)[17]

The evaluation of orthopantomograms (OPGs) using Rood and Shehab[17] criteria revealed varying frequencies of seven radiographic signs. Among these, interruption of the canal was the most frequently observed feature, present in 85.71%,30 cases**.** Darkening of roots was the second most common finding, appearing in 77.14%,27 cases**.** Deflection of the root was noted in 31.43%,11 cases**,** while narrowing of the root was present in 22.86%,8 cases**.** Less frequently observed signs included dark and bifid apex 14.28%, 5 cases**,** diversion of the canal 14.28%, 5 cases and narrowing of the canal 14.28%, 5 cases (Table 4 & Graph 3)**.** These findings suggest that the canal's interruption and the root's darkening are the most reliable indicators of potential nerve involvement. A single patient may exhibit multiple criteria concurrently as defined by Rood and Shehab[17] radiographic assessment. In our study, only 3 cases had a single criteria present as defined by Rood and Shehab's,15 cases had 2 criteria present, 14 cases had 3 criteria present and 3 cases had 4 criteria's present.

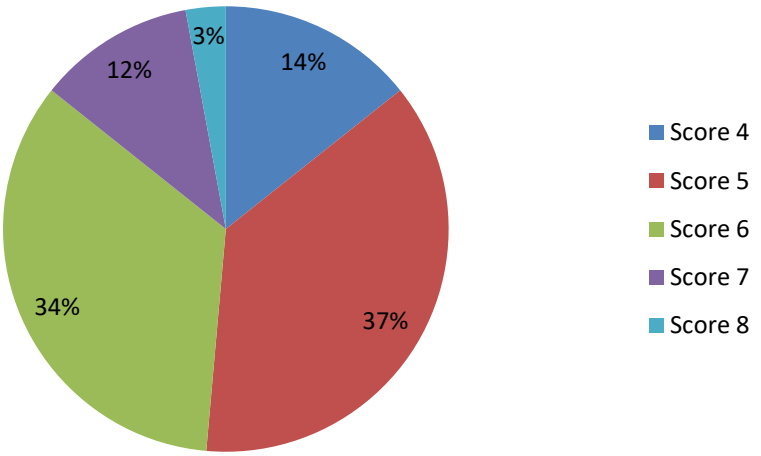


Graph 3: OPG evaluation based on seven radiographic signs (Rood and Shehab criteria)[17]

	Frequency	Percent
Score 4	5	14.3
Score 5	13	37.1
Score 6	12	34.3
Score 7	4	11.4
Score 8	1	2.9

Table 5: Distribution of Pederson difficulty scores among study participants

The distribution of Pederson's difficulty scores for lower impacted third molars indicates a predominance of moderate to severe difficulty extractions. The most common difficulty scores were Score 5 (37.1%) and Score 6 (34.3%), suggesting that the majority of impacted teeth presented with a moderate to significant level of difficulty for extraction. Score 4, indicating a lower level of difficulty, was observed in 14.3% of cases, while Score 7**,** reflecting a higher difficulty, was present in 11.4% of cases. Only a small fraction of cases were classified as Score 8 (2.9%), representing the most challenging extractions (Table 5 & Pie chart 1).

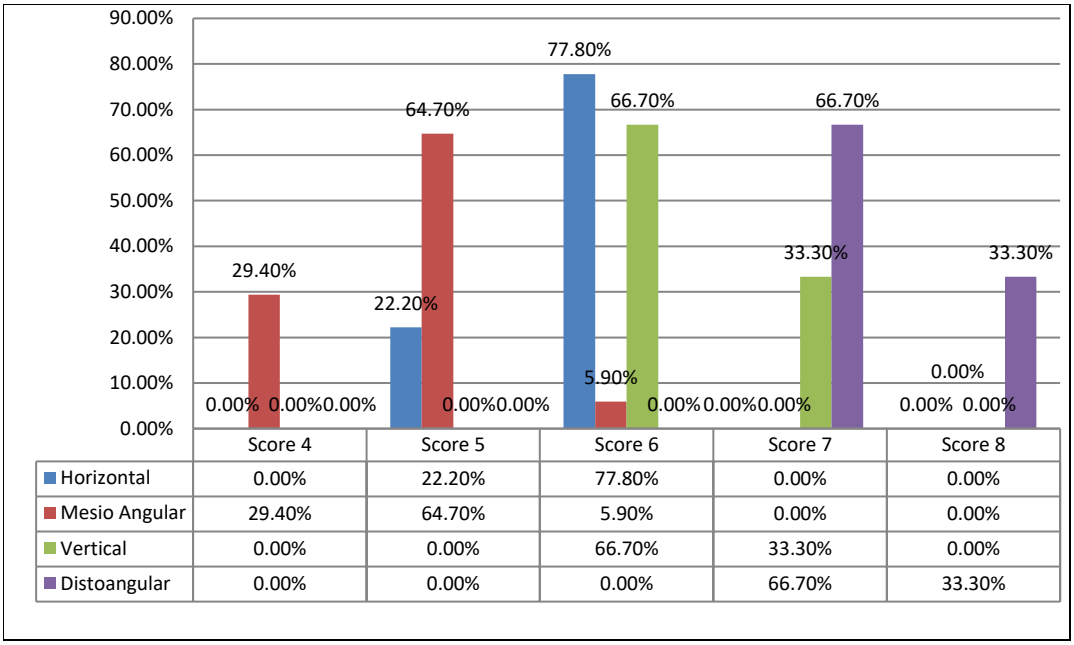


Pie chart 1: Illustrating the percentage distribution among study participants indicating the relative frequency of each difficulty level in mandibular third molar extraction

	Score 4	Score 5	Score 6	Score 7	Score 8	P value
Horizontal	0	2	7	0	0	0.001(Sig)
	.0%	22.2%	77.8%	.0%	.0%	
Mesio-angular	5	11	1	0	0	
	29.4%	64.7%	5.9%	.0%	.0%	
Vertical	0	0	4	2	0	
	.0%	.0%	66.7%	33.3%	.0%	
Disto-angular	0	0	0	2	1	
	.0%	.0%	.0%	66.7%	33.3%	

Table 6: Correlation between Pederson's difficulty score and angulation of impacted mandibular third molar

The results of Pederson's difficulty scores based on the type of impaction show distinct patterns in the distribution of difficulty levels across different impaction types. For horizontal impactions, most cases were categorized as Score 6 (77.8%), indicating a moderate to severe difficulty, with a small percentage in Score 5 (22.2%). No horizontal impactions were classified as Score 4**,** Score 7 or Score 8**.** In contrast, mesio-angular impactions showed a more evenly distributed range of difficulty scores, with the majority classified as Score 5 (64.7%), followed by Score 4 (29.4%) and a small percentage in Score 6 (5.9%). No mesio-angular impactions were assigned Score 7 or Score 8. For vertical impactions**,** the majority were classified as Score 6 (66.7%), with Score 7 affecting 33.3% of cases, and no vertical impactions were given Score 4 or Score 5**.** Finally, disto-angular impactions showed a high level of difficulty, with Score 7 in 66.7% and Score 8 in 33.3% of cases (Table 6 & Graph 4). The p-value of 0.001 indicates that the differences in difficulty scores across the types of impactions.



Graph 4: Pederson Difficulty Scores based on type of impaction

	Frequency	Percent
Buccal	12	34.3
Lingual	12	34.3
Inter-radicular	1	2.9
Inferior	10	28.6

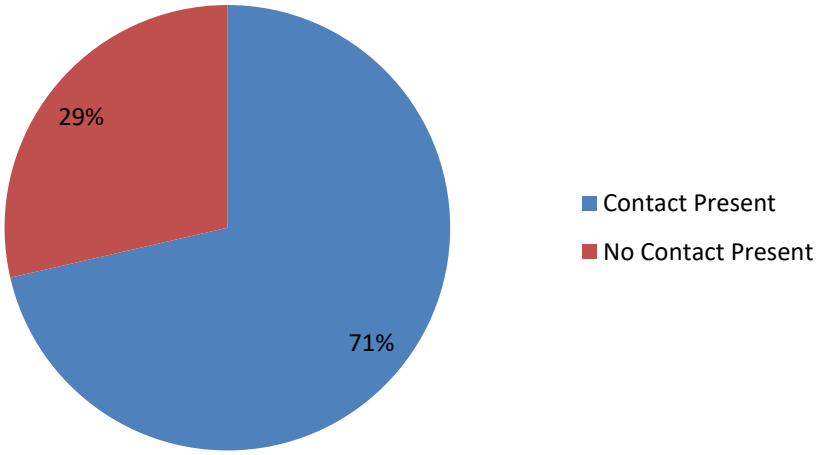
Table 7: Positional relationship of roots of impacted molar with the inferior alveolar nerve

The most common relationships were buccal and lingual, each observed in 34.3% of cases, indicating that the IAN were positioned either on the buccal or lingual side of the root apex of the impacted mandibular third molar. A smaller proportion of cases were classified as inferior (28.6%), meaning the inferior alveolar nerve was positioned below the root apex of the third molar. Also, only a small percentage of cases were identified as inter-radicular (2.9%), where the inferior alveolar nerve was located between the roots of IMTM (Table 7). These findings suggest that in the majority of cases inferior alveolar nerve was positioned either buccally, lingually or inferiorly in relation to the root apex of the lower impacted third molar.

	Frequency	Percent
Contact Present	25	71.4
No Contact Present	10	28.6

Table 8: Contact of the impacted third molar with IAN

The relationship between the lower impacted third molar and the IAN shows that in 71.4% of cases, 25 instances had contact present between the root apex of impacted molar and the IAN. In contrast, 28.6% of cases, 10 instances showed no contact present (Table 8 & Pie chart 2). In this study, out of 25 contact cases, 2 cases had 1 criteria present as per by Rood and Shehab, 9 cases had 2 criteria's present, 12 cases had 3 criteria's present and 4 cases had 4 criteria's present. These results indicate that the majority of impacted third molars are in direct contact with the IANC, which could have implications for the difficulty of extraction and the potential complication of IAN nerve injury during surgery.

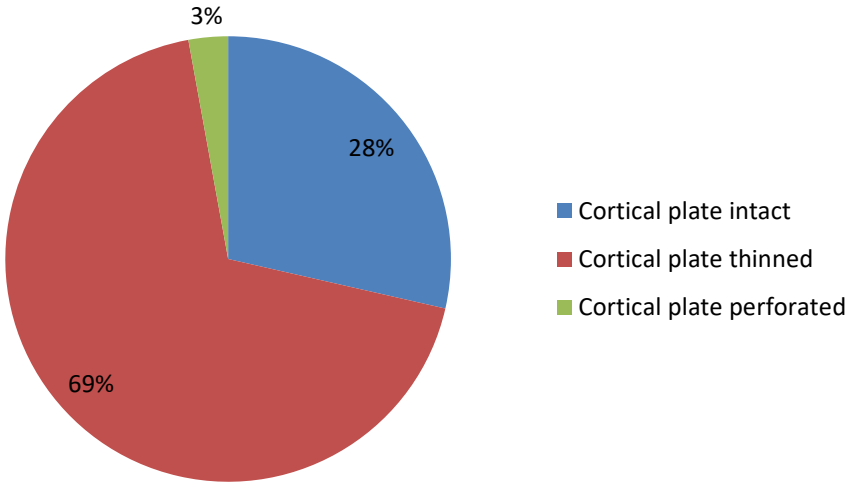


Pie chart 2: Contact of the impacted third molar with IAN

	Frequency	Percent
Cortical plate intact	10	28.57
Cortical plate thinned	24	68.57
Cortical plate perforated	01	2.86

Table 9: Relation of the impacted third molar with the cortical plate

The assessment of the lower impacted third molar in relation to the cortical plate revealed notable variations in cortical integrity. The majority of cases (68.57%, 24 cases) exhibited thinning of cortical plate, suggesting a significant risk of nerve injury. Out of 24 cases in which cortical plate is thinned, 9 cases had 2 criteria's present as per given by Rood and Shehab's, 11 cases had 3 criteria's present, 4 cases had 4 criteria's present. In 28.57% ,10 cases, the cortical plate remained intact, indicating minimal risk of nerve injury (Table 9 & Pie chart 3). However, perforation of the cortical plate was observed in only 2.86%,1 case, in this 3 criteria's were present as per by Rood and Shehab's signifying a rare but severe effect (higher chances of nerve injury- Direct contact).



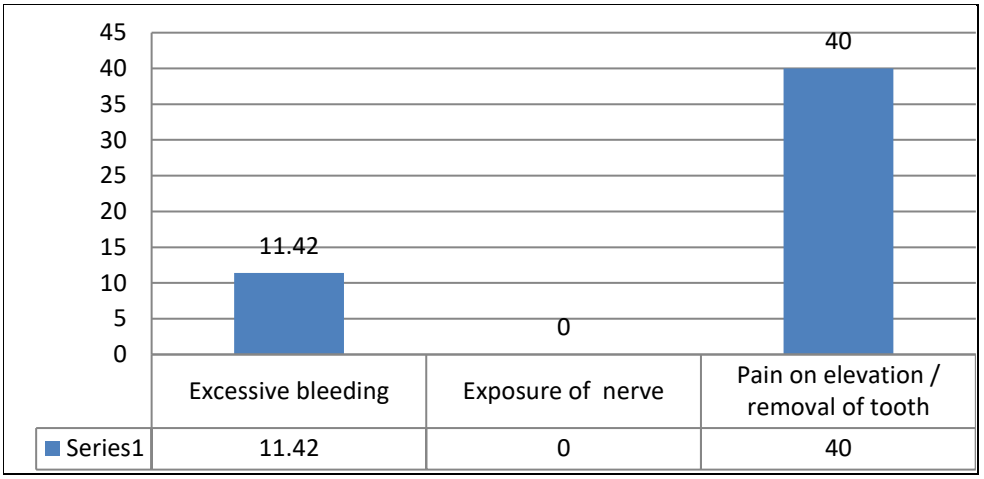
Pie chart 3: Relation of the impacted third molar with the cortical plate

	Frequency	Percent
Excessive bleeding	04	11.42
Exposure of nerve	00	0.00
Pain on elevation / removal of tooth	14	40

Table 10: Intra-operative assessment of the study subjects

These results suggest that while excessive bleeding was relatively uncommon only seen in (4 cases) out of (4 cases) 3 cases had 3 criteria's present as per by Rood and Shehab's and 1 case had 2 criteria present. A significant proportion of patients (14 cases) (40%) experienced pain during the elevation or removal of the lower impacted third molar. In this out of (14 cases) 1 cases had 1 criteria present as per by Rood and Shehab's, 6 cases had 2 criteria present, 5 cases had 3 criteria present and only 2 cases had 4 criteria's present (Table 10 & Graph 5).

The absence of nerve exposure is a positive outcome, indicating that the procedure did not involve significant complications related to nerve damage.

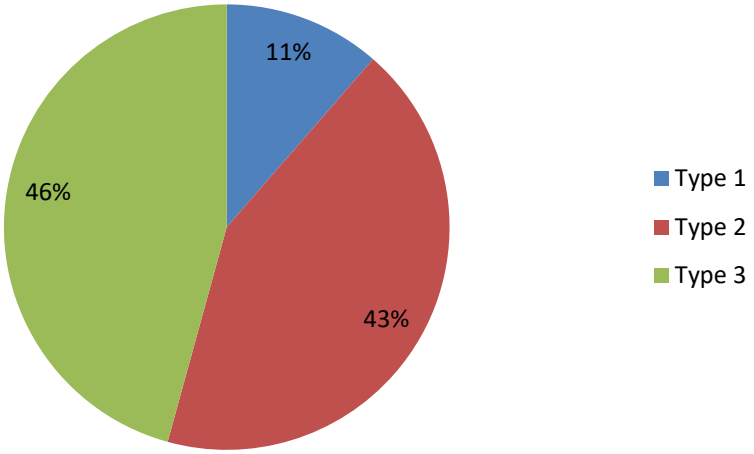


Graph 5: Intra-operative assessment of the study subjects

	Frequency	Percent
Type 1	4	11.4
Type 2	15	42.86
Type 3	16	45.71

Table 11: Morphologic shape of the bone in the third molar region

The majority of cases exhibited Type 2 morphology (42.86%), followed by Type 3 (45.71%) and Type 1 (11.4%). These findings suggest that the bone morphology in the lower third molar region in this study was predominantly of Type 2 and Type 3, with Type 3 being the most common (Table 11 & Pie chart 4).

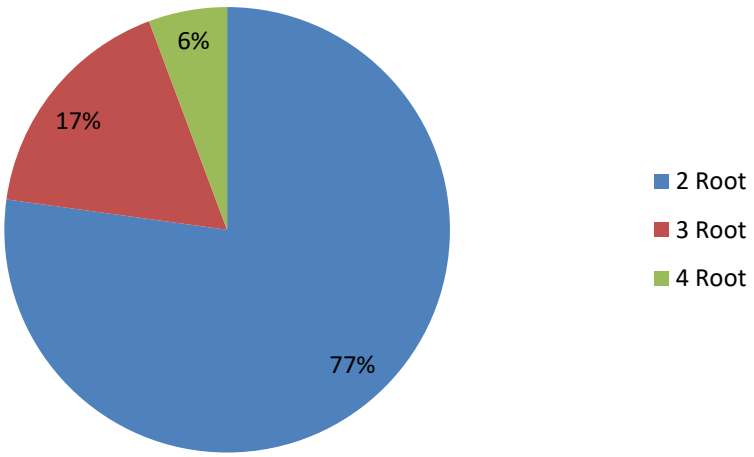


Pie Chart 4: Morphologic shape of the bone in the third molar region

	Frequency	Percent
2 Root	27	77.1
3 Root	6	17.1
4 Root	2	5.7

Table 12: Number of roots among study subjects

The majority of impacted third molars had 2 roots (77.1%), followed by 3 roots (17.1%) and a small proportion with 4 roots (5.7%). These results suggest that the majority of IMTM in the present study had a double root, with a smaller percentage having three or four roots (Table 12 & Pie chart 5).



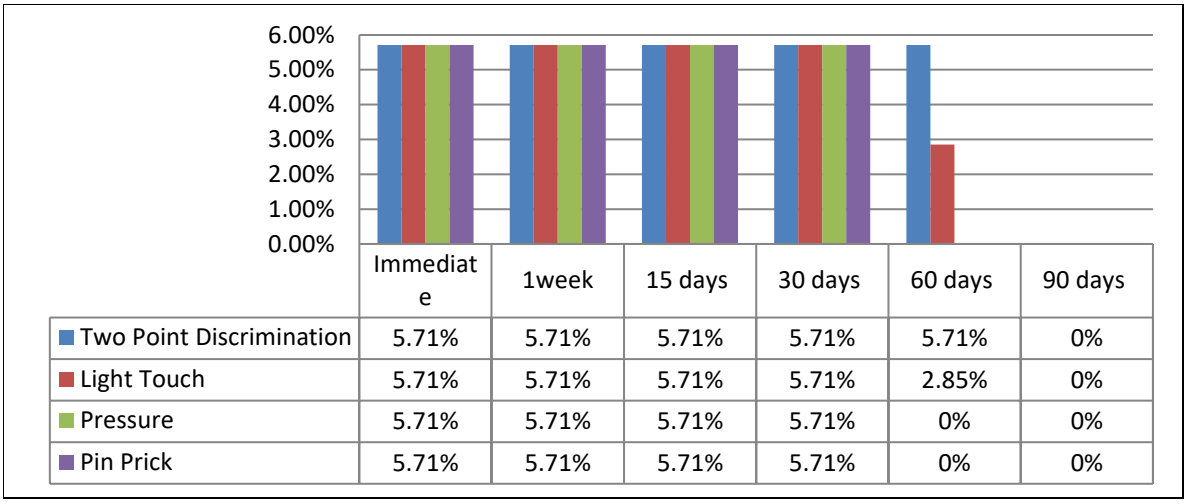
Pie chart 5: Number of roots among study subjects

	Immediate	1week	15 days	30 days	60 days	90 days
Two Point Discrimination	02 (5.71%)	02 (5.71%)	02 (5.71%)	02 (5.71%)	02 (5.71%)	00(0%)
Light Touch	02 (5.71%)	02 (5.71%)	02 (5.71%)	02 (5.71%)	01(2.85%)	00(0%)
Pressure	02 (5.71%)	02 (5.71%)	02 (5.71%)	02 (5.71%)	00(0%)	00(0%)
Pin Prick	02 (5.71%)	02 (5.71%)	02 (5.71%)	02 (5.71%)	00(0%)	00(0%)

Table 13: Neurosensory deficit among study subjects

The neurosensory deficit among the study subjects over various time points is summarized as follows:

- Two Point Discrimination test: At each follow up period (immediate, 1 week, 15 days, 30 days, and 60 days), 2 cases (5.71%) showed a deficit. By 90 days, no cases exhibited a deficit.
- Light Touch test: 2 cases (5.71%) showed a deficit at immediate, 1 week, 15 days, 30 days, and 60 days. There was a slight improvement by 60 days, with only 1 case (2.85%) showing a deficit.
- Pressure test: 2 cases (5.71%) had a deficit at immediate, 1 week, 15 days, and 30 days. No deficits were observed by 60 days and 90 days.
- Pin Prick test: Similarly, 2 cases (5.71%) showed a deficit at immediate, 1 week, 15 days, and 30 days. By 60 days and 90 days, no deficits were present (Table 13 & Graph 6).



	Immediate	1week	15 days	30 days	60 days	90 days
Two Point Discrimination	5.71%	5.71%	5.71%	5.71%	5.71%	0%
Light Touch	5.71%	5.71%	5.71%	5.71%	2.85%	0%
Pressure	5.71%	5.71%	5.71%	5.71%	0%	0%
Pin Prick	5.71%	5.71%	5.71%	5.71%	0%	0%

Graph 6: Neurosensory deficit among study subjects

STATISTICAL ANALYSIS

The data for this study was entered into Microsoft Excel 2007 and analyzed with the SPSS statistical program 23.0 Version. Descriptive statistics included frequency and percentage. Mean and standard deviations. The level of significance for the current study was set at 5%.

The ordinal and nominal variables will be compared using the Chi Square test and the Z-Test for proportions.

Chi Square Test

Chi-square is a statistical test that is commonly used to compare observed data to data that we would expect to obtain based on a specific hypothesis. When an analyst attempts to fit a statistical model to observable data, he or she may question whether the model truly represents the facts. How "close" are the observed values to the expected values of the fitted model? The chi-square goodness of fit test is a statistical tool that addresses this issue. This test is commonly used to investigate the relationship between variables in two-way tables by comparing the assumed model of independence to the observed data. In general, the chi-square test statistic has the form

$$X^2 = \sum \frac{(\text{observed - expected})^2}{\text{expected}}$$

If the computed test statistic is large, then the observed and anticipated values are not near, and the model fits the data poorly.

DISCUSSION

An impacted tooth is one that cannot emerge properly due to causes such as malposition, insufficient space, or physical obstructions along its eruption path. Left untreated, impacted teeth might lead to discomfort, pain, and various dental issues.[1]

The surgical removal of the lower impacted tooth is a common procedure in oral surgery, performed for both therapeutic and prophylactic reasons.[2,3] However, it is frequently associated with complications such as discomfort, inflammation, bleeding, dry socket, infection, and restricted mouth opening (trismus).[4,5] Among these, the most concerning is transient or permanent damage to the IAN.[4] The mandibular canal, a critical anatomical structure within the mandible, houses the IAN, which provides sensation to the teeth, gums, and lower lip. During the surgical removal of the lower impacted tooth, understanding the precise location and course of the canal relative to the teeth and surrounding bone is paramount. The mandibular canal, where IAN runs parallel to the mandibular artery and vein, has a close association with the impacted third molar root, with frequent modification in caliber, shape and corticalization in correspondence with the tooth. The incidence of temporary inferior alveolar nerve (IAN) injury following the removal of impacted lower third molars varies between 0.6% and 5.3%, while the likelihood of permanent injury remains under 1%.[4] Such complications not only affect patients through potential sensation loss but also carry significant medicolegal implications.[6,7] Thus, pre-operative radiographic examination is essential to predict and mitigate these risks.

Various radiographic modalities are employed for pre-operative assessment, including periapical radiographs, orthopantomogram (OPG), cone-beam computed tomography (CBCT), Denta-Scan, and computed tomography (CT).[3,4] Preoperative radiographic evaluation of the anatomy of the IMTM and its relation with the canal is important to determine the risk of IAN injury. OPG is widely used as an initial examination tool to assess root morphology, angulation of impacted teeth, and the type of impaction.[8,9] However, as a two-dimensional imaging tool, OPG cannot accurately determine the spatial connection between the inferior alveolar canal (IAC) and the lower impacted third molar. The overlapping or distortion of images can lead to misinterpretation and incorrect clinical decisions.[10-12] These limitations greatly reduce its diagnostic accuracy and effectively rule it out as a necessary assessment prior to surgical removal of the lower wisdom tooth.

CBCT has emerged as a superior imaging technique, offering three-dimensional (3D) visualization of anatomical structures. One of the key concerns that can be visualized with

(3D) radiographs is the absence of corticalization of the mandibular canal that is in contact with the tooth. It enhances pre-operative risk assessment by providing detailed information on the spatial relationship between the IAC and the IMTM. Compared to OPG, CBCT offers advantages such as high resolution, 3D imaging, buccolingual visualization, and lower radiation exposure.[11-13] These benefits make CBCT particularly valuable in cases where the lower third molar is in close proximity to the IAC or there is a significant risk of nerve injury.[14] CBCT has a substantially lower radiation dose than CT, making it suitable for applications that were previously difficult to justify due to radiation exposure concerns. However, due to its high cost, it is not suggested as the primary radiography technique. In this study we evaluated the risk of IAN exposure or injury following 3rd molar surgery by comparing the risk assessment based on two dimensional (OPG) and three dimensional (CBCT) radiographs along with its clinical outcome. For the purpose of the study patients with impacted mandibular third molar, showing close proximity to IAN canal on two-dimensional radiograph as per Rood and Shehab[17] classification were included. Detailed case history, necessary radiographic assessment was recorded as per proforma. Type of impaction was recorded preoperatively (Winter's Classification[56] and Pell and Gregory Classification[57]). The types of relationship between the IMTM (impacted mandibular third molar) and the IANC (inferior alveolar nerve canal) on the panoramic radiographs were categorized based on the Rood & Shehab[17] classification. Third molars in close proximity to the (IAN) were assessed using CBCT. The results of Winter's classification[56] for impacted mandibular third molars, as assessed through both OPG (Orthopantomogram) and CBCT imaging, show identical distribution across the different categories. The majority of impacted third molars were classified as mesio-angular (48.6%), followed by horizontal (25.7%) and vertical (17.1%). A smaller percentage of cases were classified as disto-angular (8.6%), with no cases identified as inverted in either imaging modality. The statistical analysis, indicated by the p-value of 1.000, reveals that there is no significant difference between the two imaging modalities (OPG and CBCT) in terms of classification distribution, suggesting that both imaging methods provide similar results in assessing the angulation and position of lower impacted third molars. The identical distribution of Winter's classification for IMTM using OPG and CBCT can be attributed to the nature of angulation assessment, which primarily relies on mesiodistal inclination rather than three-dimensional spatial relationships. According to Sasurla et al (2005)[28] OPG provides a broad panoramic view of the dentition and is widely used for initial assessment of impacted mandibular third molars. Despite its inherent limitations, such as image distortion and magnification errors, OPG has been shown to be reliable in determining

tooth angulation when classifying impactions using Winter's criteria. Since Winter's classification is based on the angle of the long axis of the third molar relative to the adjacent second molar in a mesiodistal plane, OPG remains effective for this specific assessment. CBCT offers three-dimensional visualization and enhanced accuracy for assessing anatomical relationships between impacted teeth and adjacent structures, such as the inferior alveolar nerve.[58] However, when evaluating Winter's classification, which is based on two-dimensional angulation, CBCT does not provide a significant advantage over OPG. The ability to view the impacted tooth from multiple planes in CBCT does not change the mesiodistal classification but rather enhances the assessment of buccolingual positioning and proximity to vital structures. [59,60] The statistical analysis shows no significant difference between OPG and CBCT in classifying Winter's impactions. This suggests that the added three-dimensionality of CBCT does not influence the classification outcome, reinforcing that OPG remains a valid tool for angulation-based assessment. Studies by Nakagawa Y et al (2007)[61] and Gupta S et al (2019)[62] have reported similar findings, concluding that while CBCT is indispensable for surgical planning, particularly in evaluating nerve proximity and bone morphology, it does not necessarily alter the classification of impaction types.

The results of Pell and Gregory's classification for impacted mandibular third molars show a distribution across different positions and classes. In terms of position, the majority of cases were classified as Position-B (71.4%), followed by Position-A (25.7%), and a very small percentage were Position-C (2.9%). For the class distribution, most cases fell under Class-2 (97.1%), with a small proportion in Class-1 (2.9%), and no cases were classified as Class-3. According to Quek SL et al (2003),[63] these findings indicate that Position-B impactions are the most common, likely due to partial eruption of the third molar between the occlusal plane and the cervical line of the second molar, which is a frequent clinical presentation in young adults where space is inadequate for complete eruption. Similarly, Hashemipour MA et al (2013)[64] suggested, Class-2 impactions, where the mesiodistal diameter of the crown is partially covered by the ramus, are often observed due to insufficient jaw length posteriorly, which hampers full eruption. The absence of Class-3 cases may suggest that severe ramal obstruction is relatively rare in the studied population, possibly due to earlier intervention or anatomical variation.[65] These results are consistent with previous studies conducted by Gupta A et al (2012)[66] & Yilmaz S et al (2016)[67] which also reported Position-B and Class-2 as the most common types of mandibular third molar impactions, reflecting a broader epidemiological pattern that can guide clinical decisions related to third molar extractions.

The high frequency of interruption of the canal (85.71%) and darkening of the root (77.14%)

as observed in OPGs using Rood and Shehab criteria in this study suggests their strong association with potential inferior alveolar nerve (IAN) involvement. According to the radiographic assessment criteria established by Rood and Shehab[17], individual patients may exhibit multiple indicators simultaneously. In the present study only 3 cases demonstrated a single criteria as per Rood and Shehab[17], 15 cases exhibited 2 criteria's, 14 cases presented with 3 criteria's, and 3 cases met 4 of the defined criteria. Out of all criteria's darkening of root, interruption of the white line of the canal and deflection of the root were the most common. According to Rood and Shehab's criteria (1990),[17] the inferior alveolar canal (IAC) is typically outlined by cortical bone, which appears as a radiopaque border on OPG. An interruption or loss of this cortical outline suggests direct contact or penetration by the third molar roots, increasing the risk of nerve injury. Sambrook et al. (2014)[68] reported that when the canal is disrupted or appears discontinuous, it may indicate pressure, displacement, or even encroachment by the impacted tooth, which can lead to paresthesia or neurosensory deficits postoperatively. Darkening of the root on OPG is often associated with the thinning of dentin or loss of mineralization where the IAN is in close proximity. This phenomenon occurs because the nerve is either compressed or embedded within the root structure, making extractions more challenging and increasing the risk of nerve damage (Yıldırım et al., 2019).[69] Studies have shown that roots exhibiting darkening or narrowing are often adjacent to or wrapped around the IAC, reinforcing the importance of preoperative CBCT evaluation in such cases to confirm nerve involvement (Tantanapornkul et al., 2007).[22] In a study by Neves FS et al (2012)[11] interruption of the IAC and darkening of the root are the most reliable radiographic indicators of potential IAN involvement because they directly reflect alterations in bone and root structure due to nerve proximity. Given the limitations of OPG in assessing buccolingual positioning, CBCT should be considered when these signs are present to accurately evaluate the risk of nerve damage.

The distribution of Pederson's difficulty scores for impacted mandibular third molars indicates a predominance of moderate to severe difficulty extractions. The most common scores were Score 5 (37.1%) and Score 6 (34.3%), suggesting that the majority of impacted third molars presented with a moderate level of surgical difficulty. Score 4, representing lower difficulty, were observed in 14.3% of cases, while Score 7, indicating higher difficulty, was present in 11.4%. Only a small fraction (2.9%) were classified as Score 8, which reflects the most challenging cases for extraction with severe difficulty. These findings underscore that the extraction of impacted mandibular third molars often involves considerable anatomical complexity, primarily due to factors such as depth of impaction, angulation, and proximity to

the ramus and second molar, which are integrated into Pederson's difficulty index.[72] CBCT provides precise spatial orientation of the impacted tooth, allowing for accurate classification of horizontal, mesio-angular, vertical, and disto-angular impactions (Tantanapornkul et al., 2007).[22]

This is particularly useful for horizontal and disto-angular impactions, which require extensive bone removal and have the highest Pederson scores (Gupta et al., 2014).[66]

The results of Pederson's[70] difficulty scores based on the type of impaction reveal distinct and clinically significant patterns in the distribution of difficulty levels across different impaction types.

For horizontal impactions, the majority of cases were classified as Score 6 (77.8%), with a smaller proportion as Score 5 (22.2%). These findings align with the anatomical complexity associated with horizontally impacted third molars, which typically require extensive bone guttering, sectioning of the tooth, and careful retraction of soft tissues, particularly due to their orientation and proximity to the mandibular canal. [71,72] The absence of Scores 4, 7, or 8 suggests that while horizontal impactions are uniformly challenging, they seldom reach the extreme difficulty or involve additional complicating factors (e.g., deeply embedded roots or dense bone) required for the highest scores.[72]

In contrast, mesio-angular impactions demonstrated a more evenly distributed difficulty profile, with Score 5 (64.7%) being most common, followed by Score 4 (29.4%) and Score 6 (5.9%). Santosh P et al (2015)[73] & Monaco G et al (2011)[74] suggest that this pattern reflects the typical clinical behavior of mesio-angular impactions, which are frequent and moderately difficult due to their partial eruption and more accessible position. These impactions often require moderate bone guttering and have a lower risk of nerve injury, making them more manageable compared to horizontal or disto-angular types. For vertical impactions, the predominance of Score 6 (66.7%) and Score 7 (33.3%) suggests increased complexity, despite the seemingly favorable vertical angulation. These teeth are often deeply seated, with root development close to the inferior alveolar nerve, and may be covered by dense bone, raising the level of surgical challenge.[75] Their vertical orientation can also limit access for elevation and may necessitate tooth sectioning, especially if adjacent molars obstruct the path of removal.[76] Disto-angular impactions were predominantly associated with the highest surgical difficulty levels, with 66.7% classified as Score 7 and 33.3% as Score 8. These cases are widely regarded as among the most technically challenging due to the posterior angulation of the crown, which is often positioned beneath the anterior border of the mandibular ramus and may be obscured by surrounding bone and soft tissue. This anatomical orientation

significantly limits surgical access and increases the risk of intraoperative complications, particularly injury to the lingual nerve or adjacent structures during removal. [63,77]

When relationship of impacted molar to the inferior alveolar nerve was evaluated, the most common relationships were buccal and lingual, each observed in 34.3% of cases, indicating that the inferior alveolar nerve were positioned either on the buccal or lingual side of the root apex of impacted mandibular third molar. A small proportion of cases were classified as inferior (28.6%), meaning the inferior alveolar nerve was positioned below the root apex of impacted mandibular third molar. Only a small percentage of cases were identified as interradicular (2.9%), where the inferior alveolar nerve was located between the roots of impacted mandibular third molar. These findings suggest that in the majority of cases inferior alveolar nerve are positioned either, buccally, lingually and inferiorly in relation to the root apex of third molar, which could be significant for surgical planning.

In our study the relationship between the impacted third molar and the IAN showed that in 25 cases (71.4%), “contact” was present between the impacted molar and the IAN. In contrast, 10 cases (28.6%) showed “no contact” present. Amongst these 25 cases, 9 presented with two criteria’s,12 with three criteria’s, and 4 with four criteria’s as defined by Rood and Shehab. The most commonly observed criteria in the study were darkening of the root, interruption of the canal, and deflection of the root. In our study, we observed neurosensory deficit’s in 2 cases out of 25 “contact” cases. These results indicate that the majority of impacted third molars are in direct contact with the IAN, which could have implications for the difficulty of extraction and the potential for nerve injury during surgery. This relationship is of clinical importance during preoperative assessment. Radiographic evaluation using panoramic or CBCT imaging helps in determining the degree of contact and planning accordingly whether for conventional or surgical extraction. Cases with evident risk of nerve contact may warrant referral to an oral surgeon, especially if located close to the inferior alveolar nerve canal, which further elevates surgical risk.[19,22] The high prevalence of IAN contact cases in this dataset underscores the need for careful radiographic evaluation and treatment planning, particularly in younger patients where bone density is higher and third molars are more likely to be embedded.

The assessment of impacted mandibular third molars in relation to the cortical plate revealed notable variations in cortical bone integrity, which holds clinical significance in both diagnosis and surgical planning. Majority of 24 cases (68.57%) exhibited thinning of the cortical plate. Amongst these 24 cases, 9 presented with two criteria’s, 11 with three criteria’s, and 4 with four criteria’s as defined by Rood and Shehab.[17] In contrast, 10 cases (28.57%)

retained an intact cortical plate, and only 1 case (2.86%) demonstrated canal perforation. In our study, 2 cases of neurosensory deficit's were observed. In one case, the cortical plate was thin, and in the other case, the cortical plate was perforated. In both cases, one with a perforated cortical plate and the other with a thin cortical plate, three criteria's described by Rood and Shehab were present: Darkening of the root, interruption of the canal, and deflection of the root. In a separate study by Ghaeminia et al. (2011), diversion of the canal was identified as the most reliable diagnostic marker for the absence of cortication, followed by darkening of the root and interruption of the white line of the canal. According to Monaco G et al (2011)[74] & Obiechina AE et al (2001)[75,] thinning of the cortical plate indicates a progressive remodeling or resorption of bone due to pressure exerted by the impacted tooth, particularly in cases with prolonged impaction or when the tooth is deeply embedded. This thinning can increase surgical difficulty, reduce the bone's ability to withstand surgical forces, and raise the risk of iatrogenic fracture or postoperative complications such as delayed healing. The presence of an intact cortical plate in approximately one-third of cases suggests that in certain patients, especially those with partial impactions or where the tooth has not exerted significant pressure, bone remodeling is minimal. These cases often require less invasive techniques and have a lower risk of postoperative complications.[71] On the other hand, perforation of the cortical plate, although rare (2.86%), signifies a severe and localized bony response to chronic impaction. According to previous studies by Lopes V et al (1995)[78] & Bodner L et al (2003)[79] such perforation can be due to chronic infection, cystic expansion, or direct pressure from the tooth, and may increase the risk of complications such as pathological fractures, fistula formation, or communication with adjacent anatomical spaces. Evaluation of cortical plate integrity is best achieved using cone-beam computed tomography (CBCT), which provides detailed information on bone thickness, defects, and proximity to adjacent structures like the lingual nerve or inferior alveolar canal.[80]

Thus, the high prevalence of cortical plate thinning observed in this study emphasizes the need for thorough radiographic evaluation and individualized surgical planning based on the degree of bony involvement.

The results of the intraoperative assessment revealed that excessive bleeding was relatively uncommon only seen in 4 cases. 3 cases out of 4 with excessive intra-operative bleeding demonstrated the presence of three Rood and Shehab criteria's, whereas 1 case with excessive bleeding met with two of the criteria's. In 3 cases of excessive intra-operative bleeding, pre-op CBCT findings showed thinning of the cortical plate, while in 1 case, the cortical plate was

found to be intact. None of the cases, however had paresthesia in the post-op phase. A significant proportion of 14 cases (40%) experienced pain during the elevation or removal of the impacted third molar. Amongst these 14 cases, 1 case had 1 criteria present as per Rood and Shehab[17], 6 cases had 2 criteria's present, 5 cases had 3 criteria's present, and only 2 cases had 4 criteria's present. In 10 out of the 14 cases with excessive pain, pre-operative CBCT findings showed thinning of the cortical plate, in 3 cases, the cortical plate was intact, and in 1 case, the cortical plate was perforated. Two cases developed paresthesia in the post-operative phase. Pre-operative CBCT findings for those cases showed thinning and perforation of the cortical plate. This intraoperative pain may reflect challenges associated with anatomical variations, deep impactions, or incomplete local anesthesia, particularly in lower third molar surgeries where inferior alveolar nerve blocks may not always provide complete coverage. [81,82] According to Van Wijk et al (2013)[83] & Moore PA et al (2013)[84], pain during surgery can also be linked to excessive manipulation, tissue resistance, or anxiety, all of which can influence the patient's pain perception and overall surgical experience. The absence of nerve exposure is a notable and positive finding, indicating that none of the extractions involved direct trauma to the inferior alveolar or lingual nerves. This suggests careful surgical technique and proper radiographic evaluation prior to the procedure, allowing surgeons to avoid high-risk cases or employ techniques to minimize nerve involvement, such as tooth sectioning or coronectomy where indicated.[19,85] Therefore, these findings indicate that while pain during extraction is relatively frequent and may require better intraoperative pain management strategies, the lack of nerve exposure reflects effective preoperative assessment, surgical planning, and execution, ultimately minimizing serious complications.

The analysis of bone morphology in the mandibular third molar region revealed that the majority of cases exhibited Type 2 morphology (42.86%), closely followed by Type 3 (45.71%), while Type 1 morphology was observed in only 11.4% of the cases. The predominance of Type 2 and Type 3 morphologies in this study suggests a greater surgical challenge, as these morphologies often require bone guttering or sectioning for tooth removal. Type 3 morphology, being the most common, is associated with reduced buccal bone, increasing the likelihood of lingual root proximity and potential lingual plate perforation, especially during elevation.[86] Such cases demand careful flap reflection, precise osteotomy, and minimal force application to avoid complications such as lingual nerve damage or mandibular fracture. On the other hand, Type 1 morphology, though least common, is considered more favorable for extraction as it provides adequate bone mass for controlled

elevation and lower risk of root exposure or nerve proximity. The limited incidence of Type 1 in this study implies that most cases may necessitate advanced surgical skills and possibly the use of CBCT imaging for detailed preoperative evaluation.[41]

The majority of impacted third molars had 2 roots (77.1%), followed by 3 roots (17.1%) and a small proportion had 4 roots (5.7%). These results suggest that the majority of impacted mandibular third molars in this study had a double root, with a smaller percentage having three or four roots. These findings are consistent with the known anatomical variability of third molars and highlight the predominance of the double-rooted form in the mandibular arch. The mandibular third molar is among the most morphologically variable teeth in the human dentition. The presence of two roots-typically one mesial and one distal is considered the most common root configuration in mandibular third molars and reflects a simpler developmental pattern similar to that of second molars.[87,88] The occurrence of four roots (5.7%), although rare, is a significant finding. Such teeth may have unfused accessory roots or a bifurcation in one of the main roots, which can easily go undetected without 3D imaging techniques like CBCT. These teeth pose increased risks during extraction due to unanticipated root complexity, leading to prolonged surgical time, increased bone removal, or postoperative complications such as residual root fragments or nerve irritation.[89,90]

The evaluation of neurosensory function in patients undergoing mandibular third molar extraction revealed a low incidence of transient neurosensory deficits, with all modalities showing recovery over time. In this study, neurosensory deficits were observed in only 2 out of 35 cases. In both instances, three radiographic indicators described by Rood and Shehab[17] were identified: darkening of the root, deflection of the root, and interruption of the white line of the mandibular canal. Preoperative CBCT imaging revealed direct contact between the root apex of the impacted third molar with the inferior alveolar nerve canal (IANC) in both cases. Additionally, CBCT findings demonstrated cortical plate perforation in one case and significant thinning in the other case. These radiographic features suggest a potential correlation between specific imaging markers and an increased risk of postoperative neurosensory disturbances. Obliteration of the white line has previously been reported as a valuable predictive factor for postoperative paresthesia, as shown in the study by Blaeser[91]. Furthermore, Kim JW[92] observed that hooked or deflected roots pose greater difficulty during extraction, often necessitating extensive bone guttering. This increased surgical complexity may elevate the chances of trauma to the IAN, thereby contributing to postoperative sensory impairment.

The most commonly affected tests were the two-point discrimination test, light touch test,

pressure sensation test, and pin prick sensation test, each showing a 5.71% deficit rate (2 cases) in the immediate postoperative period. According to Renton T et al (2005)[85] these neurosensory impairments likely stem from minor trauma or compression of the inferior alveolar nerve (IAN) or, in rare cases, the lingual nerve, during third molar surgical manipulation. The proximity of deeply impacted lower third molar, especially in horizontal or disto-angular positions, to the mandibular canal increases the risk of such temporary deficits. In particular, root morphology - such as bulbous or curved roots extending toward the canal - may heighten nerve contact during elevation or root sectioning. The persistent 5.71% deficit observed for two-point discrimination test and light touch test until 60 days reflects the sensitivity of mechanoreceptors and slower regeneration of fine-touch nerve fibers.[93] However, complete recovery in two-point discrimination test by 90 days and improvement in light touch test (down to 1 case, 2.85%) by 60 days indicate that these were neuropraxic injuries rather than axonotmesis or neurotmesis, which aligns with the typically self-limiting nature of mild IAN disturbances.[81] Recovery in pressure sensation test and pin prick test sensation by 60 days in all patients further supports this, as deep-pressure and nociceptive fibers tend to recover more quickly than fine discriminatory ones.[94] The complete absence of neurosensory deficits by 90 days in most modalities also suggests minimal permanent nerve injury, likely due to the use of careful surgical technique and proper case selection.

The assessment of lower impacted third molars using classification systems, radiographic criteria, and difficulty evaluation provides valuable insights into their management. Mesio-angular impactions emerged as the most common type, followed by horizontal, vertical, and disto-angular impactions. The classification patterns indicate that most impacted third molars are positioned in a way that requires careful surgical planning to avoid complications. [57]

The depth and spatial relationship of these impactions further highlight the challenges associated with their removal. Most impacted teeth were partially covered by bone, suggesting that surgical extractions often involve bone guttering and sectioning of the tooth to facilitate extraction.[64] Understanding these patterns is essential for selecting the appropriate surgical approach and minimizing postoperative complications.

Radiographic evaluation revealed that certain radiographic signs are strong indicators of potential nerve involvement. Features such as interruption of the mandibular canal and darkening of the root were the most commonly observed, emphasizing the importance of detailed imaging in preoperative planning. Identifying these signs allows clinicians to take precautions to prevent nerve damage during extraction.[19,41]

Disto-angular and horizontal impactions require more complex surgical techniques due to their deep positioning and close proximity to vital structures. Mesio-angular and vertical impactions, while also challenging, tend to be more manageable, but still necessitate a strategic approach to minimize trauma and enhance recovery.[63]

In this context, CBCT has proven to be a valuable tool for improving diagnostic accuracy and surgical planning. While traditional panoramic imaging remains widely used for initial evaluation, CBCT provides a three-dimensional perspective that enhances the understanding of the tooth's position, root morphology, and its relationship with the IAN. This additional level of detail is particularly beneficial for cases where the risk of complications is higher.[29]

Overall, a thorough preoperative assessment combining clinical evaluation, radiographic analysis, and difficulty scoring is essential for ensuring safe and effective third molar extractions. The integration of advanced imaging techniques, particularly CBCT, allows for better risk assessment, improved surgical precision, and reduced complications, ultimately leading to better patient outcomes.

CONCLUSION

Cone Beam Computed Tomography (CBCT) is an essential imaging tool for evaluating the mandibular canal, including its course and relationship with adjacent anatomical structures, particularly in cases involving impacted teeth. CBCT has proven to be highly effective in assessing the three-dimensional relationship between impacted mandibular molars and the inferior alveolar nerve. It allows for accurate localization of the impacted tooth within the alveolar bone, assessment of its angulation, and its proximity to neighboring teeth and critical structures such as the nerve canal and cortical boundaries. The findings from our study can serve as a valuable reference for oral surgeons, aiding in the preoperative evaluation of the relationship between the impacted mandibular third molar (IMTM) and the inferior alveolar canal (IAC), predicting the risk of nerve injury ultimately contributing to enhanced surgical planning and clinical proficiency.

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ANNEXURE – 1

ETHICAL COMMITTEE CLEARANCE FORM

SANTOSH
Deemed to be University
(Established u/s 3 of the UGC Act, 1956)

F. No. SU/2023/2480[23] Dated: 26.09.2023

Subject: Grant of Ethical Clearance for Thesis Protocol Topic "Comparative evaluation of impact on risk assessment of inferior alveolar nerve injury or eposure after comparison of 2-D (OPG) imaging and 3-d (CBCT) imaging following 3rd molar surgery: a prospective clinical study", submitted by **Dr. RAJIV KUMAR SINGH,** MDS student of Batch 2022-2023, Department of **ORAL & MAXILLOFACIAL SURGERY.**

*****

With reference to his/her request for grant of Ethical Clearance for the Thesis Protocol entitled "Comparative evaluation of impact on risk assessment of inferior alveolar nerve injury or eposure after comparison of 2-D (OPG) imaging and 3-d (CBCT) imaging following 3rd molar surgery: a prospective clinical study", **Dr. RAJIV KUMAR SINGH** is informed that the Thesis Protocol submitted by him/her was considered by the **Screening Committee** of the Santosh Dental College & Hospital in its meetings held on 07.02.2023 & 08.02.2023. The recommendations of the **Screening Committee** were considered in detail by the Institutional **Ethics Committee** in its meeting held on **23.09.2023** and the same was **approved** by the **Ethics Committee.**

He /She is informed accordingly for further necessary action.

[DR. NARESH SHARMA]
REGISTRAR

SANTOSH DEEMED TO BE UNIVERSITY REGISTRAR GHAZIABAD, U.P.

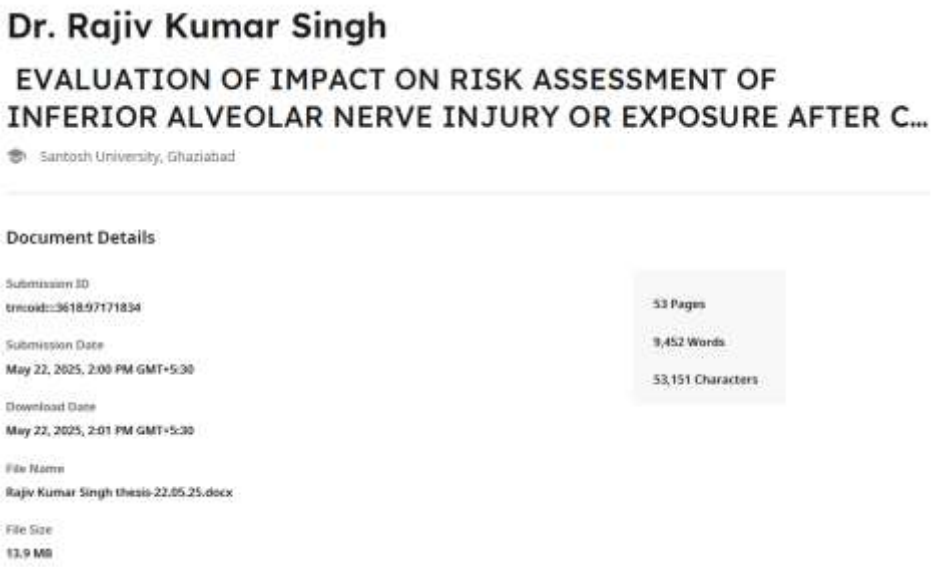
Dr. RAJIV KUMAR SINGH
MDS student of batch 2022-2023
Department of ORAL & MAXILLOFACIAL SURGERY
Email: styamo094@gmail.com

Copy to:

1. The Vice Chancellor
2. The Dean, SDC&H
3. The Dean – Research
4. The Dean – Academics
5. The Director - IQAC
6. **Dr. Amit B Lall** (Guide)
7. HOD of **ORAL & MAXILLOFACIAL SURGERY**

ANNEXURE – 2

ANTI PLAGIARISM REPORT



Dr. Rajiv Kumar Singh

EVALUATION OF IMPACT ON RISK ASSESSMENT OF INFERIOR ALVEOLAR NERVE INJURY OR EXPOSURE AFTER C...

Santosh University, Ghaziabad

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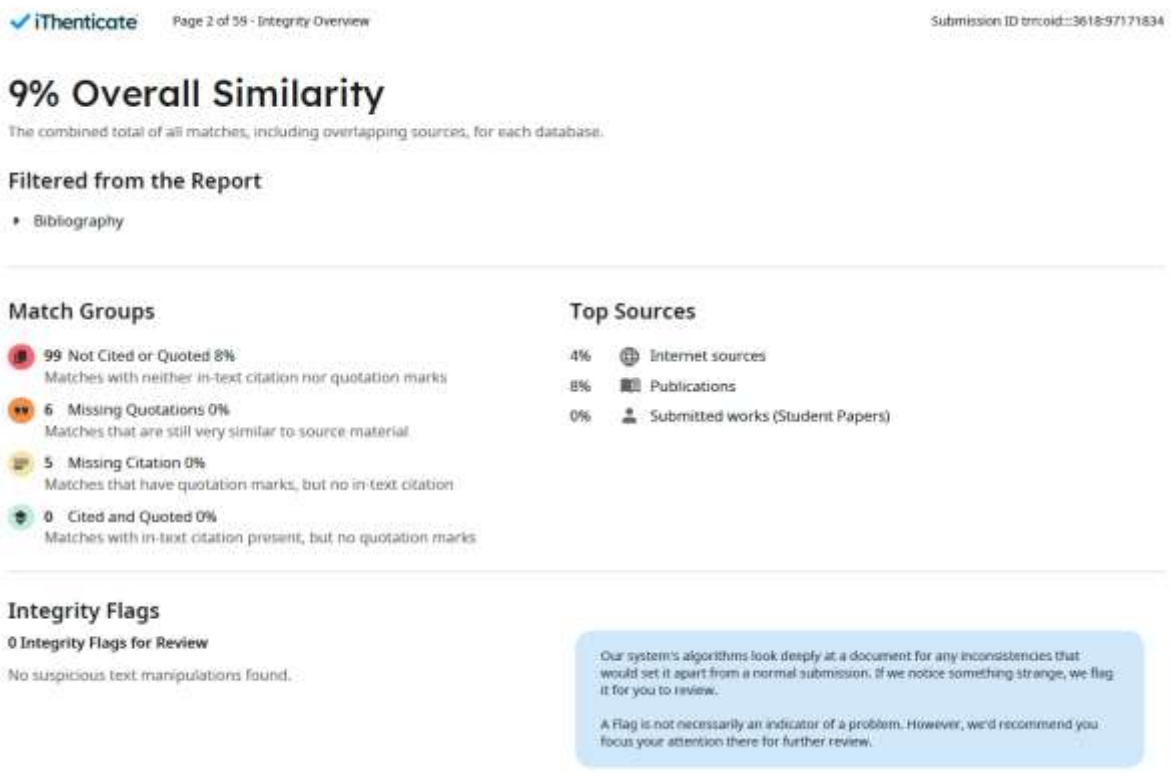

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ANNEXURE – 3

PATIENT PROFORMA

NAME:

AGE/SEX:

ADDRESS:

CHIEF COMPLAINT:

HOPI:

PAST MEDICAL HISTORY:

PAST DENTAL HISTORY:

HABITS:

GENERAL PHYSICAL EXAMINATION:EXTRAORAL EXAMINATION:

INTRAORAL EXAMINATION:

SOFT TISSUE:

Labial and Buccal mucosa:

Gingiva:

Floor of the mouth:

Palate:

Tongue:

Trismus:

Maximal Interincisal Mouth Opening (MIO) ..... mm.

HARD TISSUE:

Teeth present:

Missing teeth:

Total no. of impacted teeth:3rd molar eruption:

Type of impaction:

Relation with the opposing 3rd molar:

Decayed:

Fractured:

PROVISIONAL DIAGNOSIS:

BLOOD INVESTIGATIONS:

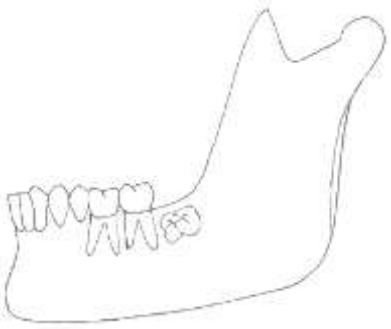
RADIOGRAPHIC INVESTIGATIONS (OPG/CBCT:)

FINAL DIAGNOSIS:

TREATMENT PLAN:

PREOPERATIVE ASSESSMENT

WINTER'S CLASSIFICATION FOR IMPACTED MANDIBULAR THIRD MOLAR



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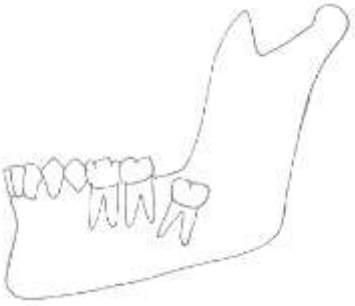
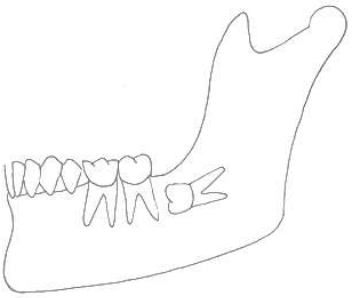


Disto-angular



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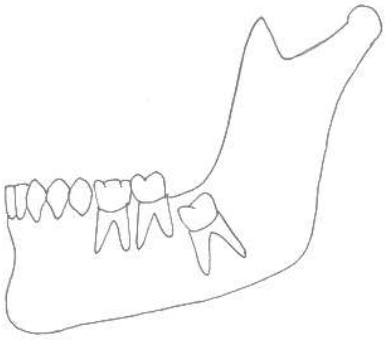
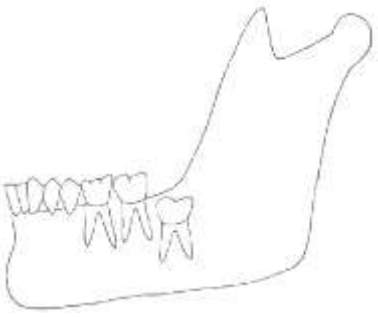


Mesio-angular



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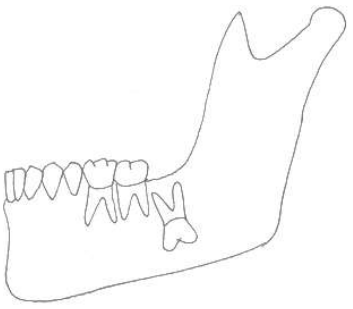
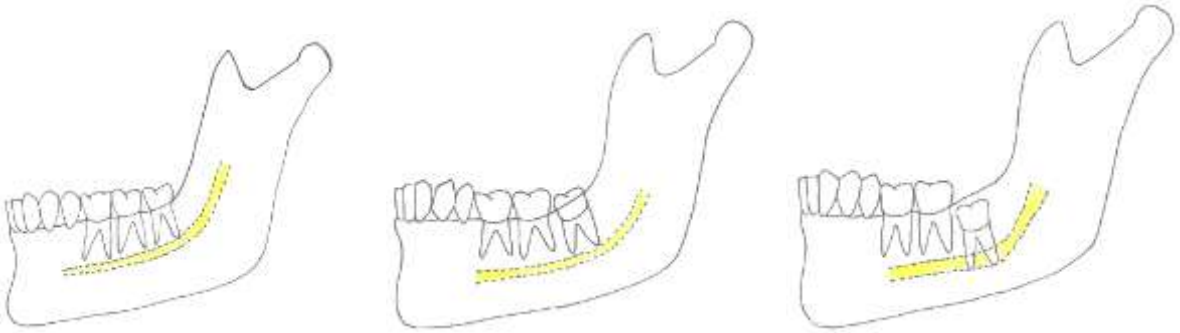
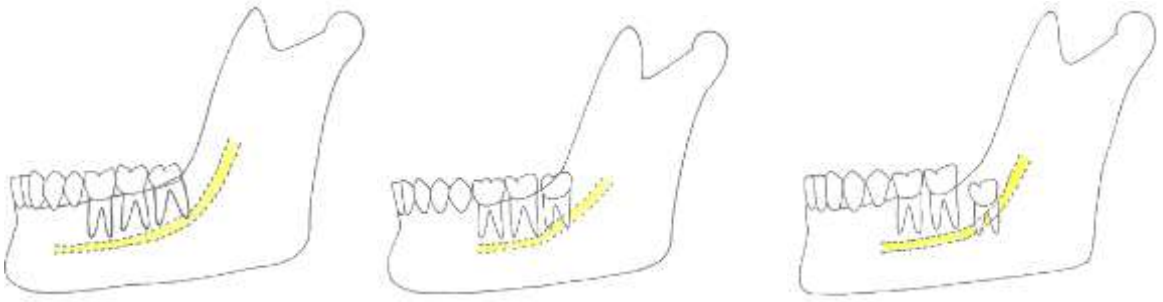


Inverted

PELL AND GREGORY'S CLASSIFICATION FOR IMPACTED MANDIBULAR THIRD MOLAR



POSITION – A **POSITION- B** **POSITION- C**



CLASS I **CLASS II** **CLASS III**

TABLE 1: PEDERSON DIFFICULTY INDEX

S. No	Classification	Difficulty index value
	Angulation	
	Mesioangular	1
	Horizontal/Transverse	2
	Vertical	3
	Distoangular	4
	Depth	
	Level A	1
	Level B	2
	Level C	3
	Ramus relationship	
	Class I	1
	Class II	2
	Class III	3

Difficulty index very difficult: 7-10, Moderately difficult: 5-7, Minimally difficult: 3-4

TABLE 2: OPG EVALUATION BASED ON SEVEN RADIOGRAPHIC SIGNS (ROOD AND SHEHAB'S CRITERIA)

RADIOLOGICAL SIGN	PRESENT / ABSENT
DARKENING OF ROOT	
DEFLECTION OF ROOT	
NARROWING OF ROOT	
DARK & BIFID APEX OF ROOT	
INTERRUPTION OF WHITE LINE OF CANAL	
DIVERSION OF THE INFERIOR ALVEOLAR CANAL	
NARROWING OF THE INFERIOR ALVEOLAR CANAL	

TABLE 3: EVALUATION OF CBCT BASED ON FOLLOWING PARAMETERS

CBCT FINDINGS		
Type of IMTM	a. Type A -Vertical	
	b. Type B – Horizontal	
	c. Type C – Angular	
Buccolingual relationship of (IMTM) impacted mandibular third molar and IAC (inferior alveolar canal)	a. Buccal	
	b. Lingual	
	c. Inter-radicular	
	d. Inferior	
Position of inferior alveolar canal with respect to third molar	a. Contact (no bone between IAC and Third Molar)	
	b. No Contact (bone between IAC and Third Molar)	
	c. Cortical plate intact	
	d. Cortical plate thinned	
	e. Cortical plate perforated	
Morphologic shape of the bone in the third molar region`	a. Type 1 Round (round on both buccal and lingual sides)	
	b. Type 2 lingual extended (slightly straight on the buccal side with a bony extension on the lingual side)	
	c. Type 3 lingual concave (lingual concave on the lingual side and round on the buccal side)	
No. of Roots	a. 1 Root	
	b. 2 Root	
	c. 3 Root	

INTRAOPERATIVE ASSESSMENT

- Excessive bleeding
- Exposure of nerve
- Pain on elevation/removal of tooth

POSTOPERATIVE ASSESSMENT

TABLE 4: NEUROSENSORY DEFICIT

NEUROSENSORY DEFICIT OF IAN	IMMEDIATE	1 WEEK	3 MONTHS
Two Point Discrimination			
Light Touch			
Pressure			
Pin Prick			

ANNEXURE 4

INFORMED CONSENT

DEPARTMENT OF ORAL AND MAXILLOFACIAL SURGERY

SANTOSH DENTAL COLLEGE AND HOSPITAL, GHAZIABAD

"EVALUATION OF IMPACT ON RISK ASSESSMENT OF INFERIOR ALVEOLAR NERVE INJURY OR EXPOSURE AFTER COMPARISON OF 2-D (OPG) IMAGING AND 3-D (CBCT) IMAGING FOLLOWING 3RD MOLAR SURGERY: A PROSPECTIVE CLINICAL STUDY"

I, Mr. / Ms…….
S/O, D/O, W/O. ……...
Resident of ……

have been informed about all the benefits and risks during and after the surgical procedure. I am willingly participating in the study conducted by the department of Oral and Maxillofacial Surgery, Santosh Dental College and Hospital.
I should choose to withdraw from this study at any point; I will be free to do so after giving priorinformation to the concerned surgeon.

Signature of Surgeon In-charge

Date:

Signature of Patient

Date:

Signature of Parent/Guardian

Date:

शोध विषय स्वीकृति पत्र

मुह /जबड़ा शल्य चिकित्साविभाग

संतोष दंत महाविध्यालय एवं अस्पताल, गाजियाबाद

^^bosY;w,"ku vkQ bEiSDV vku fjLd ,lslesUV vkQ bUQhfj;j ,yfo;ksyj uoZ bUtjh vkSj ,Dlikstj vk¶Vj dEiSfjtu vkQ Vw Mh ¼vks-ih-th½ besftax ,.M Fkzh Mh ¼lh-ch-lh-Vh-½ besftax QkSyksbUx FkMZ eksyj ltZjh % v izkSLiSfDVo Dyhfudy LVMh**

मैं,श्री/श्रीमती/ ....

पुत्र/iq=h.....

...

निवासी.....

.....

.....

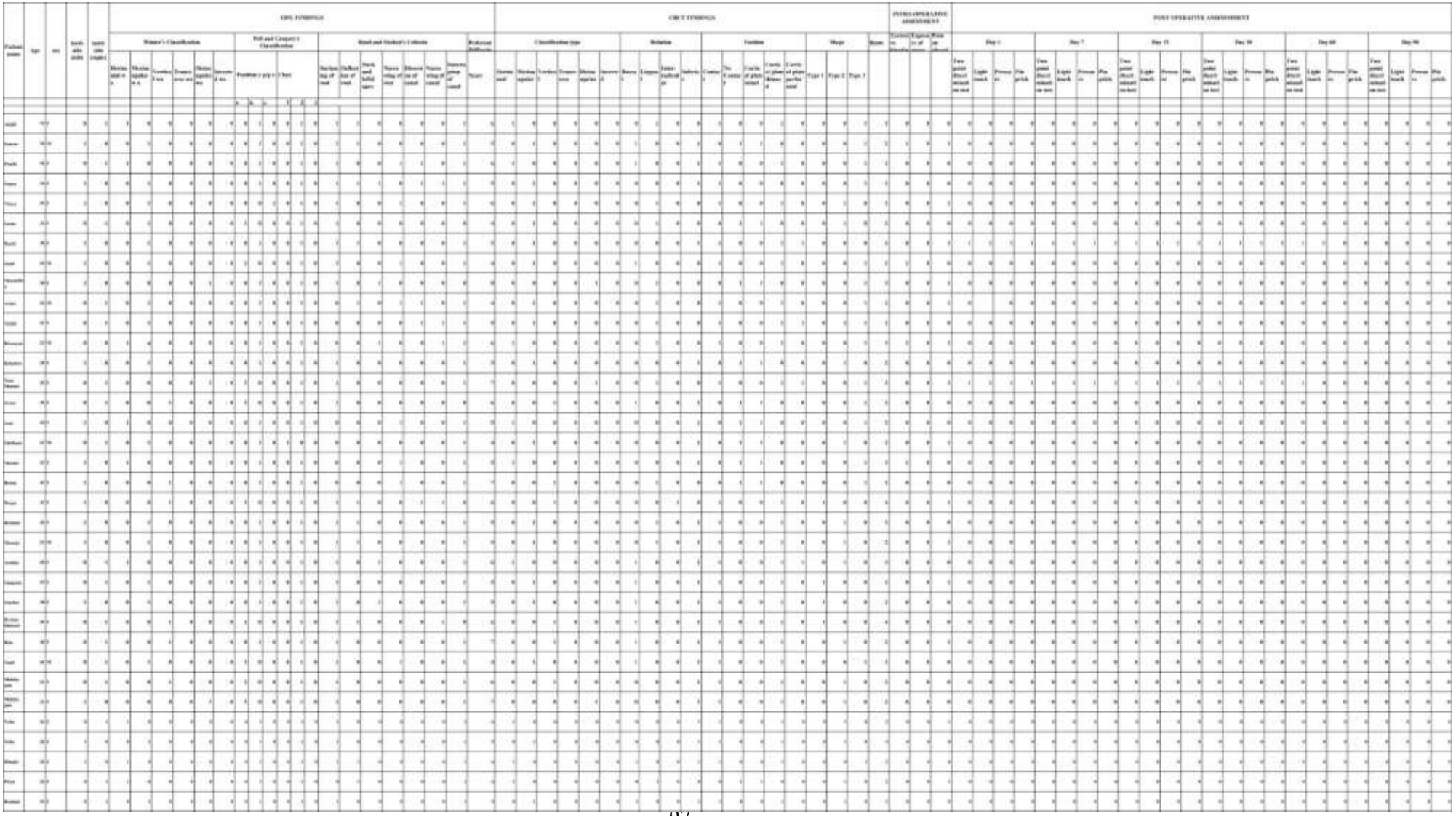
इस शल्य चिकित्सा के दौरान और उसके बाद होने वाले लाभ और जोखिम से भली- भाँति अवगत कराया गया हैं। मैं अपनी स्वेच्छा से मुँह व जबड़ा शल्यचिकित्सा विभाग, संतोष दंत महाविध्यालय एवं अस्पताल में आयोजित इस अध्ययन में अपना योगदान करना चाहती/चाहता हूँ। यदि मैं अध्ययन से किसी भी समय अलग होना चाहूँ तो चिकित्सक को सूचित करने के पश्चात अलग हो सकता/सकती हूँ।

....

चिकित्सक के हस्ताक्षर मरीज के हस्ताक्षर.

.....

संबंधी के हस्ताक्षर

ANNEXURE 5

MASTER CHART